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ABSTRACT

Presented is a general overview and summary of the 1974-1975 Sea Grant Program activities and research. Included are marine advisory services, education, coastal resources, aquaculture, fisheries, new marine products, and energy resources. (SL)

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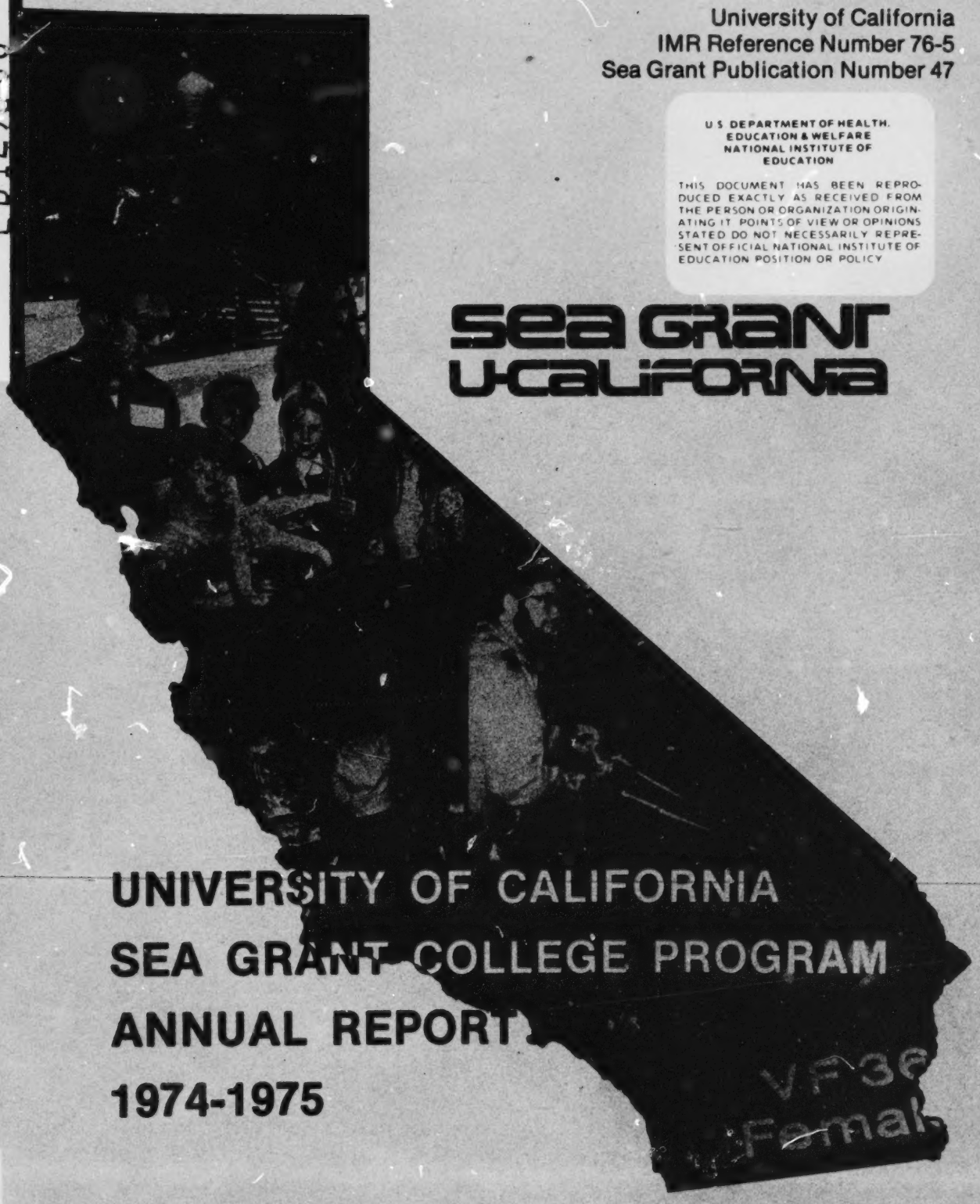

UNIVERSITY OF CALIFORNIA SEA GRANT COLLEGE PROGRAM ANNUAL REPORT 1974-1975

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A report on the University of California Sea Grant College Program for September 1, 1974 to August 31, 1975

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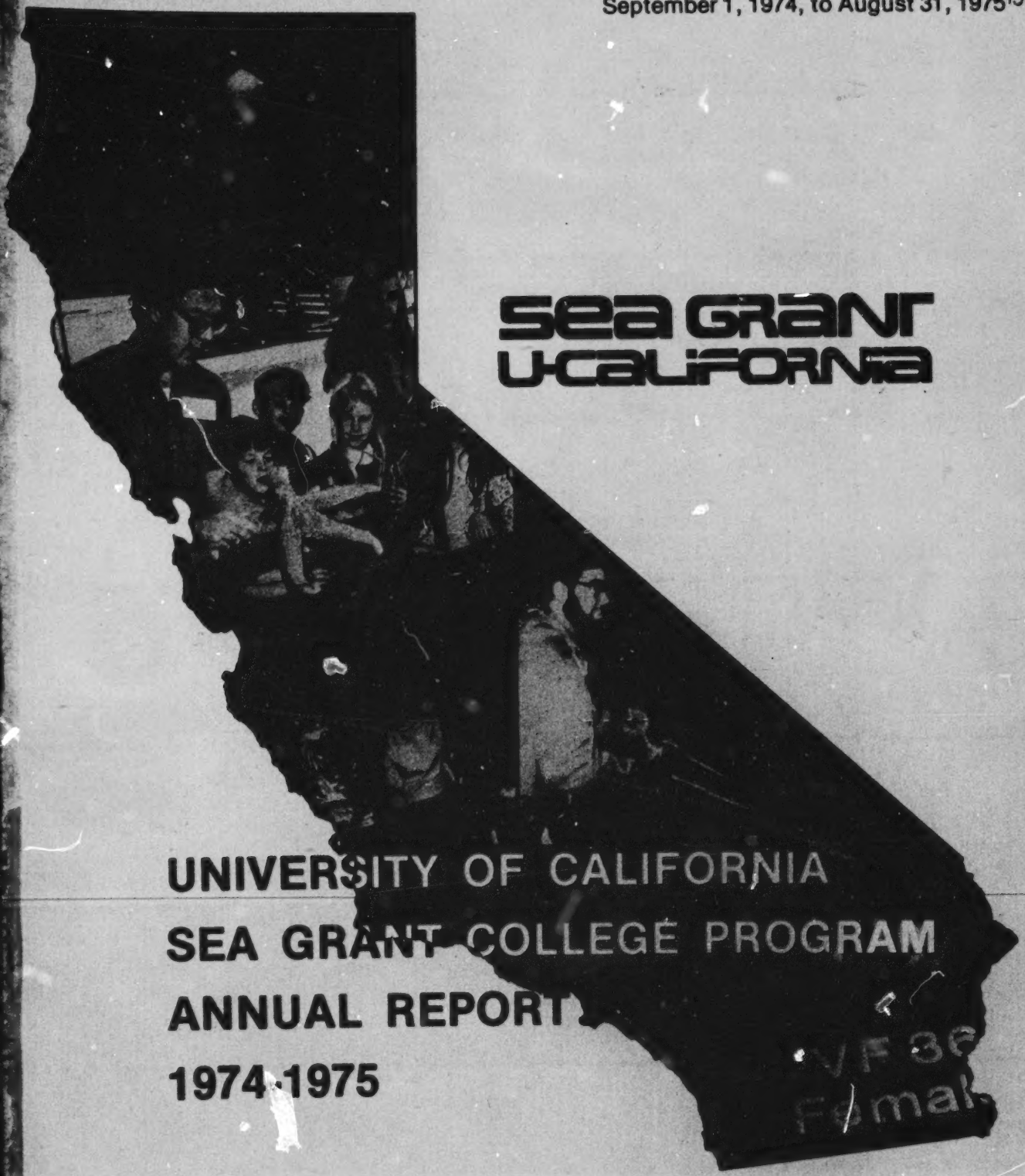

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UNIVERSITY OF CALIFORNIA
SEA GRANT COLLEGE PROGRAM
ANNUAL REPORT
1974-1975

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INTRODUCTION

The University of California Sea Grant College Program under the guidance of the then Program Manager, J. D. Frautschy, highlighted two general activity areas this past year.

The December 31, 1975 deadline for submission of the California Coastal Plan to the legislature led to an acceleration of planning activities of the California Coastal Zone Conservation Commission. These activities disclosed certain planning problem areas where Sea Grant Program investigators could usefully provide information and guidance on a timely basis through the program's Rapid Response capability. Rapid Response projects were directed to such problems as assessing the cumulative impacts of coastal development, the socioeconomic impacts of planning policies, the economic impacts of park land acquisition, and coastal policy issues relating to the area seaward of the line of the mean high tide.

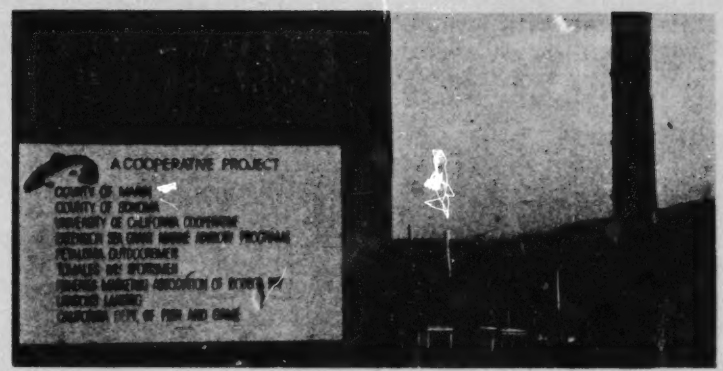
Having established a strong organizational basis with the University of California Cooperative Extension for expansion of our Sea Grant Marine Advisory services, we have developed a plan to provide marine advisory services to areas of California where such services are not now available and for coordination of marine advisory activity with the University of Southern California and Humboldt State University which also have marine advisors in their geographic areas. In June, Arthur Flechsig, a long-time staff member of the Scripps Institution of Oceanography, was appointed Marine Advisor for the San Diego area. During the coming year similar appointments will be made to provide marine advisory services in the Ventura-Santa Barbara-San Luis Obispo, Monterey Bay and San Francisco areas. There is already an advisor working in the area from Mendocino County to Marin County and marine specialists are on call from UC-Davis.

The essence of marine advisory services is the presence of local staff to facilitate the two-way flow of information between the broader marine community and the university-based researchers. The result is an education for both groups, which contributes to promoting the wise utilization, preservation, restoration, and management of coastal and marine resources for the benefit of all our citizens.

If you would like more information on the Sea Grant College Program—its publications, advisory services and research efforts—please write to:

Sea Grant College Program
A-032
University of California
La Jolla, California 92093

James J. Sullivan
Program Manager



The Tomales project

MARINE ADVISORY SERVICES

The Sea Grant Marine Advisory Program, which is part of the UC Cooperative Extension system, has continued its planned expansion with the appointment of a field agent in the San Diego County area. The advisory staff, whose primary function is to transmit information from a variety of sources to the marine community, now consists of two field agents and two statewide specialists in addition to the full time coordinator and supporting staff. A California Marine Advisory Services Plan has been prepared in consultation with the USC and Humboldt State University Program, and as a result, the UC statewide marine advisory service program will be considerably expanded in 1975-76. The Aquarium-Museum at the Scripps Institution of Oceanography was visited by almost 60,000 students in organized school groups, and members of its staff and the volunteer docents were instrumental in distributing information and displays from the Aquarium-Museum among schools and hospitals throughout the San Diego area.

Marine Advisory Programs

Maynard W. Cummings

The Marine Advisory Programs continued their educational services to the community by organizing workshops on a variety of subjects, by producing a large volume of special publications; and by putting the latest research findings into practice—introducing silver salmon into San Francisco Bay for sport fishermen, advising on the abatement of fishing boat noise for better catches, studying histamine toxicity in fish products, and in counselling fish processors on production problems.

Advisory programs, to be effective, must contain specific information and be delivered to individuals in terms they can apply to their situations. The UC Marine Advisory Program emphasizes person-to-person activities although they may, by necessity, be mass designed to reach a significant number of California's marine resource audiences. Accordingly, the Advisory staff development emphasis has been on the location of coastal advisors with area responsibilities supported by statewide specialists and campus research departments patterned after and integrated with the long-established Cooperative Extension organization of the University. In line with the 1974-75 proposal, a Marine Advisor was placed in San Diego County and recruiting was initiated for others to serve the Santa Barbara-Ventura-San Luis Obispo and Monterey-Santa Cruz areas.

It is difficult to tabulate the number of advisor-user contacts that occur because they are integral to the local staffing idea; the advisor's presence in the community provides continuing information delivery to the area he serves. Statistics of organized meetings and training workshops are impressive. In 1974-75 audiences totalling over 2600 persons, in groups of 20 to 300, attended almost 50 such workshops and meetings. Subjects included: financial assistance and marine insurance information for commercial fishermen; commercial fishing business management; salmon marketing; salmon aquaculture; artificial reefs; fishing boat refrigeration; albacore fishing; tax management for fishermen; fishery cooperatives; marine weather; underutilized fisheries; fishery development; acoustics in albacore fishing; acoustics for fishing boats; the National Fisheries Plan; and seafood education for consumers.

Seafood education for consumers

"Seafood education for consumers" proved to be the most popular subject of all. Audiences consisting of 100 to 300 housewives, teachers and home economists turned out to hear the marine resources specialist describe fish populations, biology and seafood identification; the seafood technology specialists discuss selection, preparation and preservation of seafoods, with the NMFS home economist demonstrating these techniques. Cooperative extension consumer science home advisors planned and arranged these demonstration meetings and notified their audiences while seafood companies cooperated by providing the materials.

The results of an applied research program, a Sea Grant continuing program of Oregon State University's Oceanography Department, designed to relate boat noise to fishing success, provided the basis for workshops in California. OSU acoustics researchers teamed up with UC marine advisors in this interstate research program.

The silver salmon introductory program in San Francisco Bay, which was started last year on a pilot project basis, was enthusiastically received by fishermen and well supported by State Fish and Game Department and NMFS. This was greatly expanded in 1975 with 40,000 fingerlings, up from last year's 5000, which were placed in the Tiburon holding pens. Part of the encouragement

Volunteers marking salmon at Mendocino

was due to the locating, and hooking by sport fishermen, of 3-7 lb fish from last year's experiment. Other areas joined the action and the North Coast Marine Advisor for Marin-Sonoma-Mendocino Counties had his hands full providing technical supervision and program coordination to salmon stocking ventures in all three counties. Financial support from the counties as well as from fishermen and other citizen groups is provided, and Mendocino County hired technicians who were placed under the Marine Advisor's direction.

As with the area marine advisors, the specialists, too, are daily providing information through personal contacts, telephone inquiries and by various publications. They serve, in reality, as statewide local advisors in addition to providing in-depth subject-matter support to the county staff. For example, the Seafood Technology Specialist visited processors to give direction on production problems involving refrigeration, sanitation, waste disposal, transportation, storage, processing, packaging and marketing of seafood. He also works closely with the California Seafood Industry Advisory Committee of our program, and, furthermore, was co-investigator in a Rapid Response-funded research program studying histamine toxicity in fish products.

The Marine Resources Specialist maintained contacts with fishermen's organizations, extension 4-H youth program staff, marine educational groups, University and Fish and Game Department researchers, state and federal marine resource management staffs and Sea Grant personnel in other institutions and states.

The Specialists' productivity was demonstrated by their newsletters and publications. Their joint monthly newsletter goes to a mailing list of more than 2000 in all coastal states as well as throughout California. Many complimentary letters attest to the timeliness and pertinence of its information.

The volume of special publications generated within the Advisory Program is staggering, at least to those of us who produce, maintain and distribute them. In the past year over 100,000 copies of these were sent out, many of them in response to notices of their availability published in the UC Advisory Services *Newsletter* and the *National Fisherman*. The specialists now have 18 publications in the Marine Education series and 10 Marine Briefs. Other special publications such as on fishing rope characteristics and lobster care and handling were brought out.

A Marine Advisor demonstration

Another publications development was a cooperative arrangement with the California Department of Fish and Game. Some important publications, out of print and likely to remain so due to the Department's printing budget limitations, were made available through UC Marine Advisory-Cooperative Extension-Fish and Game Department coordination.

Advisory Program staff actively participated in the National Fisheries Plan meetings in California. They set up the local preliminary meetings and played lead roles in the committee discussions at the two state level meetings held in San Francisco.

Another major program objective stated in the 1974-75 proposal was the blending and maximizing of Marine Advisory efforts statewide. The UC Advisory Program Planning Committee appointed a year earlier by the Sea Grant College Program Manager continued a series of meetings attended by University of California, Humboldt State University, University of Southern California, and Moss Landing Marine Laboratories advisory and administrative staff. After extensive discussions and many draft modifications, a draft plan was completed and presented to the National Office of Sea Grant at the time of the University of California 1975 Sea Grant Site Visit. The UC Advisory Program Coordinator served as committee chairman and principal editor of the draft plan.

The Pacific Sea Grant Advisory Program (PASGAP) leadership was vested in the UC Marine Advisory Program during 1974-75. A new member, the University of Guam, joined the existing coalition composed of the Sea Grant Marine Advisory programs of Alaska, Washington, Oregon, Hawaii and three California universities, the University of British

Columbia and the National Marine Fisheries Service's three Pacific Regions. The University of Baja California requested and received PASGAP cooperative affiliation, and informational assistance through PASGAP was instigated with the University of Idaho. Thus, it is evident that along with administrative responsibility and workshop coordination, PASGAP activities also received substantial attention in UC marine advisory activities.

The Moss Landing Marine Laboratories have been reported upon separately in this publication.

UC Advisory Services staff contributed to the drafting of the goal and policy statement of The Resources Agency Sea Grant Advisory Panel. The Advisory Services program was carried out with the assistance of funds allocated from the Resources Agency under the provisions of the 1973 legislation authored by Senator John Stull.

Publications

Dewees, C. M., Marine Briefs No. 1: The farm credit system - A new source of fishery loans. Sea Grant Marine Advisory Publication (1975).

Dewees, C. M., and D. Gotshall, An experimental artificial reef in Humboldt Bay, California, *California Fish and Game*, 60(3), 109-127 (1974).

Dewees, C. M., and J. K. Hooper, Identifying intertidal plants and animals. U. C. Division of Ag. Sciences, Cooperative Extension, Sea Grant Marine Advisory Publication AXT-445-1 (1975).

Idem, Identifying seashore birds, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-2 (1975).

Idem, Gyotaku-Japanese fish printing, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-3 (1975).

Idem, Catching and cooking crabs, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-4 (1975).

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Idem, Freezing salt water, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-6(1975).

Idem, Sampling plankton, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-7(1975).

Idem, Marine photography, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-8(1975).

Idem, Marine resource laws and regulations, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-9 (1975).

Idem, Intertidal zonation, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-10(1975).

Idem, Ocean currents, *ibid.*, Sea Grant Marine Advisory Publication AXT-445-11(1975).

Idem, Developing local 4-H marine science programs, *ibid.*, Sea Grant Marine Advisory Publication 4-H-242 (1975).

Idem, Physical oceanography, *ibid.*, Sea Grant Marine Advisory Publication 75-LE/2233 (1975).

Idem, Estuary ecology, *ibid.*, Sea Grant Marine Advisory Publication 75-LE/2245 (1975).

Idem, Ecology of the intertidal zone, *ibid.*, Sea Grant Marine Advisory Publication 75-LE/2246 (1975).

Idem, Biological oceanography, *ibid.*, Sea Grant Marine Advisory Publication 75-LE/2255 (1975).

Idem, Marine mammals, *ibid.*, Sea Grant Marine Advisory Publication LE/2274 (1975).

Idem, Major commercial fisheries in California, *ibid.*, Sea Grant Marine Advisory Publication LE/2272 (1975).

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Idem, Marine Briefs No. 4: Preparation of shark and skate, Sea Grant Marine Advisory Publication (1975).

Dewees, C. M., and B. Wyatt, Characteristics of rope used in the fishing industry. U. C. Division of Ag. Sciences, Cooperative Extension, Sea Grant Marine Advisory Publication, Leaflet 2727 (1975).

Dewees, C. M., and E. A. Yeary, Marine Briefs No. 8: Marine cost sheet - 62 ft. Eureka trawler. Sea Grant Marine Advisory Publication (1975).

Idem, Marine Briefs No. 9: Marine cost sheet - 45 ft. Eureka troller and crabber. Sea Grant Marine Advisory Publication (1975).

Price, R. J., Marine Briefs No. 2: Paralytic shellfish poisoning and red tides. Sea Grant Marine Advisory Publication (1975).

Idem, Marine Briefs No. 6: Spiced and pickled seafoods. Sea Grant Marine Advisory Publication (1975).

Idem, Marine Briefs No. 7: Mercury in seafood. Sea Grant Marine Advisory Publication (1975).

Wyatt, B., and L. Sykes, Marine Briefs No. 5: Medical care for commercial fishermen. Sea Grant Marine Advisory Publication (1975).

Cooperating Organizations

American Shellfish Enterprises, Inc., Moss Landing, California

California Department of Fish and Game, Long Beach, Monterey, Morro Bay, Sacramento and Santa Barbara, California

California Fisheries Association, Los Angeles, California

California Seafood Institute, Sacramento, California

Coastal Zone Commission, San Francisco, California

Commercial Fishermen's Organization of Morro Bay, California

Counties of Marin, Mendocino, Sonoma and Ventura, California

Fishermen's Marketing Association of Bodega Bay, California

Fort Bragg Salmon Trollers Marketing Association, California

Golden Gate Sportfishers, San Francisco, California

Half Moon Bay Fishermen's Marketing Association, California

International Shellfish Enterprises, Inc., Moss Landing, California

Japan Airlines, San Francisco, California

Moss Landing Fishermen's Marketing Association, California

National Marine Fisheries Service, La Jolla, Terminal Island and Tiburon, California

Pacific Ocean Farms, Carmel, California

Petaluma Outdoorsmen, California

Port San Luis Commercial Fishing Boat Owners and Commercial Fishermen, Inc., California

Salmon Unlimited, Mendocino, California

San Francisco Tyee Club, California

Santa Cruz Fishermen's Marketing Association, California

Sausalito Fishermen's Marketing Association, California

Save our Salmon, Mendocino, California

Tomales Bay Sportsmen, California

Trout Unlimited, Ventura County, California

Marine Advisory Services at Moss Landing

Moss Landing
Marine Laboratories
A/SA-1B

T. W. Thompson

Among the activities of Moss Landing Marine Advisory Services for the year were the establishment of the first complete series of workshops for commercial fishermen; the provision of an emergency diving service for disabled vessels; and an extensive training conference in marine sciences for 4-H Leaders and Junior Leaders.

The Sea Grant Marine Advisory Services program at Moss Landing Marine Laboratories (MLML) continues to benefit from the exemplary level of cooperation with the University of California Cooperative Extension. As a result of this high degree of integration, Marine Advisory Services have been extended to a wide variety of user groups in the Monterey Bay area.

Although workshops for commercial fishermen were piloted in this area during 1973-74, the first complete series was initiated this year. Six workshops were conducted throughout the year dealing with the following subjects: fathometers and sonars, albacore research, income tax procedures for commercial fishermen, refrigeration systems, the National Fisheries Plan, and seafood processing. The workshops, which reached more than 300 fishermen, were presented by specialists from Moss Landing, the University of California Extension, the National Marine Fisheries Service, Oregon State University, and the Internal Revenue Service.

Monterey Bay area commercial fishermen were also briefed by Advisory Services personnel concerning the draft of the National Fisheries Plan. In conjunction with an afternoon workshop devoted to the Plan, an evening "town hall" meeting was held at which industry reactions were recorded. At the statewide level, Advisory Services personnel from Moss Landing served as recorder, discussion leader and secretary for two "American Assembly" type conferences held in South San Francisco.

Advisory Services for the fishing industry in the Monterey Bay area also included provision of an emergency diving service for disabled vessels. This service assisted approximately 50 commercial fishermen. Efforts in this area have demonstrated the need for a small commercial diving operation in support of the local fishing fleet, and plans are presently under way to assist in developing such a service. At the request of commercial and recreational fishing interests, seven exploratory fishing cruises were conducted to investigate such problems as more efficient means of recovering lost sablefish traps, rockfish lure and bait preferences, testing of experimental fishing lures, and abundance of squid egg masses on their spawning grounds in Monterey. Finally, Advisory Services personnel supported the albacore acoustic research program being conducted by Oregon State University, providing boats and logistical support and serving as liaison between researchers and commercial fishermen.

Educational function

A second major area of emphasis in the Moss Landing program involved education of the general public. The Coordinator of Advisory Services at Moss Landing served as a member of the Salinas Chamber of Commerce's Environmental Committee. The Chamber cooperated with Advisory Services and the Marine Laboratories' student body in publicizing and presenting the annual Open House, which exposed more than 1500 individuals to aspects of the marine sciences and Sea Grant research programs.

In conjunction with the squid research program, the need for a more innovative and extensive squid cookbook was repeatedly expressed by community groups and regional personnel of the National Marine Fisheries Service. Therefore, Moss Landing Advisory Services, in cooperation with the Southwest Fisheries Region of NMFS and a major Southern California squid processor, arranged funding for the publication of such a cookbook. A consultant was located and hired, and testing and evaluation of her recipes have been completed at Terminal Island with the cooperation of the NMFS Regional Home Economist.

At the request of the editor of *Sea Grant 70's*, an article on the California Market Squid Fishery research program was prepared and was featured in the June edition. The Advisory Services editor also assisted in preparing two Sea Grant Technical Publications resulting from squid research.

In response to a request from the University of California Cooperative Extension, Advisory Services personnel, with the assistance of volunteers from the student body at the Marine Labs, presented a

three-day training conference for 4-H marine science Leaders and Junior Leaders. Thirty eight individuals from throughout the state attended a program which included tidepool, dune and bird walks; slide presentations on marine mammals, plants and invertebrates; and activity sessions dealing with such topics as fish printing, algae pressing, basic oceanography, plankton sampling and management of marine resources.

For the past two years Moss Landing Advisory Services personnel have been working with a local aquaculture firm, International Shellfish Enterprises, Inc. As a result of a request from this firm, an Advisory Services intern undertook a thesis project dealing with heavy metals in shellfish. Working with facilities at ISE and the Laboratories, Dennis Eimoto has been able to demonstrate that shellfish are able to purge themselves of a variety of toxic metals.

The Advisory Services program at Moss Landing has traditionally been involved with marine recreation, particularly scuba diving. In 1974-75 the Coordinator of Advisory Services acted as an advisor to the YMCA Pacific Region Scuba Program and is presently chairing the American National Standards Institute Committee on Recreational Diving Equipment. This position was assumed in response to a request from the Director of the National Council for Cooperation in Aquatics. The Committee, with the exception of the Chairman, is appointed by the Diving Equipment Manufacturers Association.

Cooperation with the University of California Marine Advisory Services program at the statewide level resulted in the service of the MLML Advisory Services Coordinator as a member of the University of California Advisory Services Planning Committee.

It is hoped that the foundation established cooperatively by MLML and Cooperative Extension in the Monterey Bay area will support the development of a complete regional marine extension program with a resident field agent. In preparation for the arrival of this agent, approved for 1975-76, the Advisory Services office has been moved into new quarters which are more convenient for public access.

Publications

Ally, J.R.R., R.G. Evans, and T.W. Thompson, The results of an exploratory fishing cruise for *Loligo opalescens* in southern and central California, June 5-25, 1974. MLML Tech. Publ. 75-2.

Bloom, N., Lots to learn about squid, *Sea Grant 70's*, 5(10), 6-7 (1975).

Broenkow, W.W., S.R. Lasley, and G.C. Schrader, California cooperative fisheries investigations hydrographic data report, Monterey Bay, July to December 1974, MLML Tech. Publ. 75-1.

Paper on National Fisheries Plan presented by T.W. Thompson at Annual Meetings of the Eastern Pacific Oceanic Conference, October 2-4, 1974 at Lake Arrowhead, California.

Paper on the results of the squid exploratory fishing cruise presented by T.W. Thompson at Annual Meetings of Western Society of Naturalists at Vancouver, British Columbia, December 27-30, 1974.

Paper on population dynamics of *Ascidia ceratodes* presented by Robert King at Second Miniconference on Biology and Chemistry of Tunicates at Hopkins Marine Station, Pacific Grove, California, July 26-27, 1975.

The Moss Landing Marine Laboratories News, *Sea Grant Newsletter*, Vol. III, Numbers 1, 2, and 3.

Cooperating Organizations

California Department of Fish and Game, Monterey, California

International Shellfish Enterprises, Inc., Moss Landing, California

Southwest Fisheries Region, National Marine Fisheries Service, Terminal Island, California

University of California Agricultural Extension, Santa Cruz County, California

University of California Cooperative Extension, Davis, California

Advisory Services specialist Chris Dewees teaches 4-H Club members the Japanese fish printing art form, "gyotaku"

MSI Community Education Project

Santa Barbara
A/EA-1C

Director, MSI

The Marine Science Institute has continued its educational role in the community by organizing marine laboratory tours, which have been very well attended; by installing two large aquaria, and by sponsoring a public seminar on Santa Barbara area fisheries.

Once again the Marine Science Institute has had a year of overwhelming response to its community education program. Our quarterly marine laboratory tour and display program was booked to capacity well in advance of each quarter period, and has received very favorable comment from the visiting groups. An improvement added this year was the installation of two large modern display aquaria. These have proved valuable not only for visiting groups but also for regular University classes. The presence of these more permanent tanks has also stimulated the collection of some of the rarer specimens from this region, which can now be kept for display even when locally unavailable. This year over 2600 people, primarily young students, participated in the quarterly program. This number is presently limited not by lack of response but only by our desire not to conflict with the use of space for regular University teaching activities, and by the time necessary to present an informative picture with the materials at hand. This program is one of the more highly visible marine science activities in the community.

One encouraging aspect of this small program has been its ability to reach members of communities outside the immediate Santa Barbara area. We regularly receive visitors from the Santa Maria, Carpinteria, and Ventura areas—even in cases where official announcement of the program has not been made.

A very valuable part of the success of this program is due to the work of the undergraduate and graduate biology students whom we employ to discuss displays, present information on marine science in general, and answer questions. Last year we were able to provide support for 18 students who took part in our program.

Additional involvement with the community was achieved through a cooperative program. The MSI and the Santa Barbara Underseas Foundation jointly sponsored a public seminar dealing with an important fishery for the Santa Barbara area. It was attended by representatives of both organizations and the Department of Fish and Game, by commercial fishermen, and the lay public.

Publications and Public Advisory Services

San Diego
A/P-1

James J. Sullivan

There is increasing realization that the oceans are one of our most prized natural resources. Thus, the role of an information center dealing with all aspects of oceanographic science assumes ever greater importance.

During the past year, we distributed information on the UC Sea Grant projects through special reports which included: the 1973-74 Annual Report, the bimonthly newsletter, the 1974-75 and 1975-76 Program Directories and the 1975-76 Institutional proposal.

We assisted with a number of articles describing the UC Sea Grant research and several news releases; participated in the UC dissemination of research results information program, and effected the transfer of the documents distribution responsibility to UC-Davis.

Marine Advisory Program: San Diego and Imperial Counties of California and State of Baja California, Mexico

Donald I. Eidemiller

A marine environmental advisory program may be established for the benefit of commercial and recreational users in Baja California. Seven areas along both coasts of the peninsula were selected and evaluated, where meteorological observations could be made twice daily and the data transmitted to San Diego State University.

Growing public utilization of the coastal and offshore zones of southern California, Baja California (Norte), Mexico, and the Salton Sea for a wide variety of purposes, has created the need for more accurate, sophisticated marine environmental information. At present no comprehensive meteorological or oceanographic advisories are issued on a day-to-day basis for all of the above mentioned areas.

Dedication of the Trans-Peninsular Highway (Mexico 1) in 1973 and the planned development of marinas along both coasts of Baja California will make available recreational areas hitherto accessible only by sea and air. There has been an increase in the loss of life and property since the opening of the highway, and a further substantial increase is expected until people are made aware of weather and marine conditions in the area. At this time Mexican authorities are aware of the problem but do not have the trained personnel or equipment to implement advisory services.

Air-sea rescue in Baja California by the U.S. Coast Guard is hampered because of the lack of knowledge concerning local environmental conditions. The cost involved is multiplied significantly because of the inability to plan the most expedient manner of rescue. The Salton Sea and the Gulf of California have been the sites of numerous fatal boating accidents on account of the treacherous combination of strong winds and severe storms and currents. Environmental data from existing National Weather Service stations are available for the Salton Sea area, but are not widely disseminated or in a format for general public consumption.

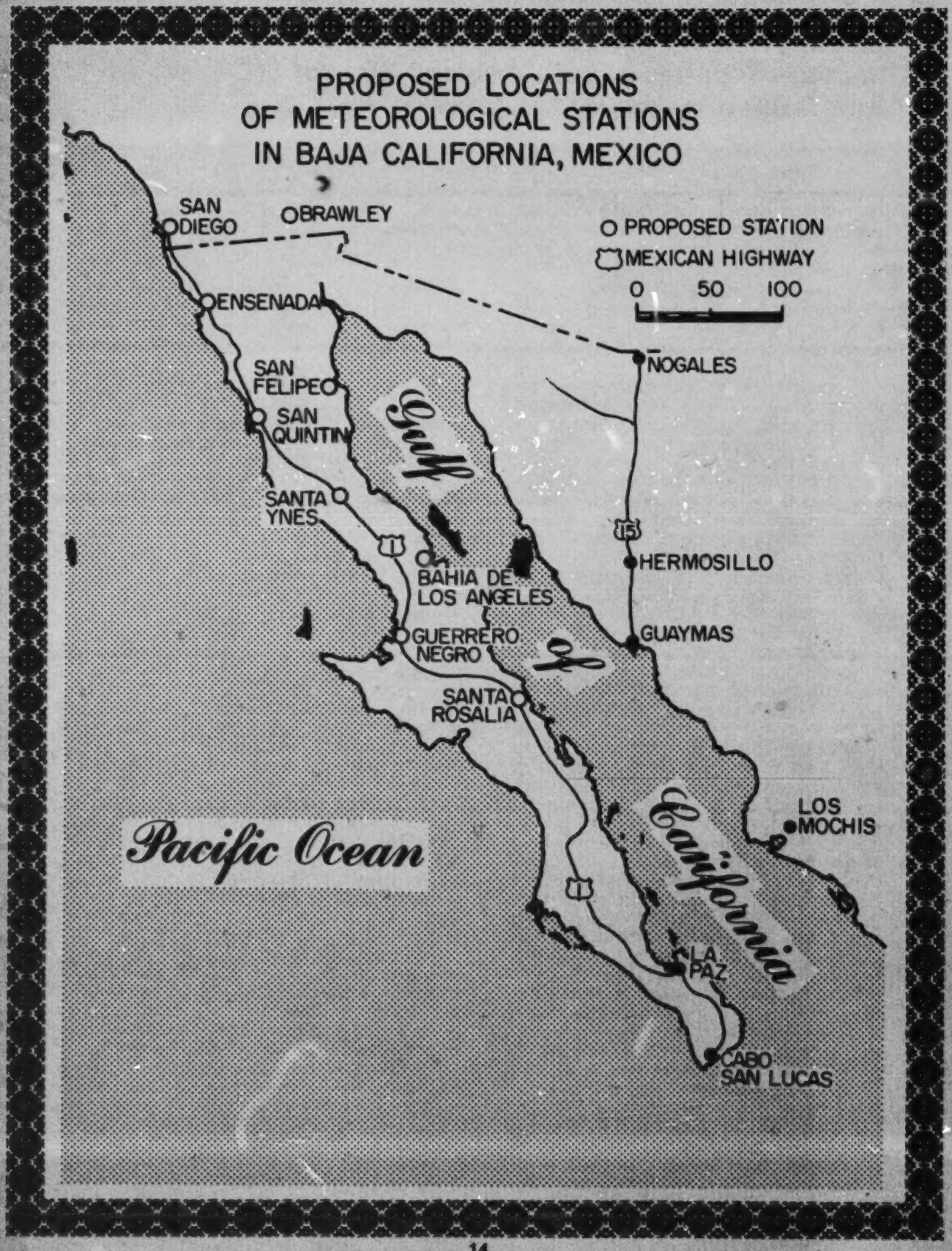
Since neither the United States nor Mexico has developed in-depth environmental advisories that are available to the general public for the area described, implementation of this proposal is greatly needed.

Environmental advisories of wide variety will be developed for marine commercial and recreational users operating out of the Port of San Diego and other harbors in San Diego County and along both coasts of Baja California (Norte), Mexico. Advisories would be used by the multitudes of campers, surfers, fishermen, recreational vehicle owners, pilots and others who, in increasing numbers, invade the shoreline of both sides of Baja California as well as the Salton Sea in Imperial County. Local commercial radio stations and other news media are constantly being asked for meteorological and oceanographic information; thus, a public service of this kind could contribute significantly to public awareness and result in the saving of lives and property. The United States Coast Guard, San Diego, is in full support of this program.

Approach to be used

In order to develop a comprehensive daily environmental advisory for this area, meteorological reporting stations will have to be established in Baja California (Norte), Mexico. When this is accomplished, data collected twice a day from these stations plus data from stations in the United States (Tucson, Arizona; Yuma, Arizona; Brawley, California; etc.) will be analyzed on the San Diego State University campus and a model environmental advisory will be prepared once daily for the (southern California-Baja, Mexico) area. This advisory will include surface weather, sea conditions, low level aviation weather, 24-36 hour weather and ocean prognostications, harbor, highway and other unusual conditions.

Prototype broadcast materials and techniques of dissemination will be developed in cooperation with San Diego State University's KPBS/FM radio station. Determination of broadcast data requirements and training of personnel will be undertaken. Experimental broadcasts and surveys of audience reaction will be conducted. Should the environmental advisories prove of substantial interest and value to the community, the National Weather Service and commercial broadcasting stations will be asked to continue this type of advisory.


PROPOSED LOCATIONS
OF METEOROLOGICAL STATIONS
IN BAJA CALIFORNIA, MEXICO
SAN DIEGO
BRAWLEY
PROPOSED STATION
MEXICAN HIGHWAY
0 50 100
ENSENADA
NOGALES
SAN FELIPE
SAN QUINTIN
Gulf
SANTA YNES
15
HERMOSILLO
BAHIA DE LOS ANGELES
GUAYMAS
GUERRERO NEGRO
of
SANTA ROSALIA
California
LOS MOCHIS
Pacific Ocean
LA PAZ
CABO SAN LUCAS

Work to date

The Environmental Data Center at San Diego State University receives environmental data from a number of sources. The U.S. Navy Environmental Data Network tieline provides specialized meteorological, climatological and oceanographic data on a continuous basis. The Center also has Nafax and Weatherwire drops, which provide adequate data for the area north of the international border. However, meteorological and oceanographic reports for Baja California are sparse and primarily limited to upper level data from Guadalupe Island off the west coast of Baja California.

A grant from the Sea Grant College Program (1974-75) permitted the investigator an opportunity to research the possibilities of establishing a network of meteorological stations in Baja California (Norte), Mexico. After several trips to the area and consultations with various Mexican officials, it is believed that such a network can be established.

The peninsula is sparsely populated and still in pristine condition. Settlements are small, communication and electrical facilities limited or non-existent. Technically trained people are not available. Therefore, the primary factors used in determining the location of the stations were the availability of electricity, communications and some type of habitation with potentially trainable personnel. Terrain differences, coastal alignment and geographic distances from each other were also considered.

Based on the above criteria, the following locations were selected (see Map):

Location	Distance in miles from U. S.-Mexican Border
West Coast, Baja California, Mexico	
Ensenada	73
San Quintin	206
Santa Inez (Catoveria)	318
Guerrero Negro	471
East Coast, Baja California, Mexico	
San Felipe	125
Bahia de los Angeles	275
Santa Rosalia	400

Recommendations

The preliminary part of this project is basically completed. To further implement this program, the following is recommended:

I. *Communications.* All Mexican stations will transmit observation data to the Centro de Investigación Científica y Educación Superior de Ensenada (CICESE), which in turn will transmit it to San Diego State University via telephone or teletype. A forecast for Baja California, Mexico, will be developed and disseminated in the southwestern United States and transmitted back into Mexico for dissemination by their communication network. Inquiry should be made to ascertain if any international laws (communication, etc.) would be violated by any of these actions. Neither American nor Mexican local officials were aware of any problems, but it is felt that this should be checked through American and Mexican federal authorities.

II. *Instruments.* Monies will need to be appropriated for the purchase and installation costs of meteorological instruments at six of the proposed seven Mexican stations. The following instruments and equipment would be considered essential:

1. Remote indicating wind system
2. Remote relative humidity system
3. Remote temperature indicator

All of the above would be electrical measuring devices.

4. Microbarograph
5. Max - Min six thermometer
6. Instrument shelter
7. Rain gage
8. Mercurial barometer
9. Cable

The above systems plus installation costs would place the price per station at approximately $3500.

III. *Personnel.* A. Mexican—A minimum of three people at each station will be trained in the procedures of making an observation. Initially a cost will be involved in the instructional program (instructor's salary, travel and per diem). No money will be paid to the observers as this activity will be part of their regular job.

B. American—Additional personnel will have to be hired to staff the Environmental Data Center and the radio station at the San Diego State University campus.

Cooperating Organizations

Arizona State University
Centro de Investigación Científica y Educación Superior, Ensenada, Baja California
Department of Tourism, Baja California, Tijuana and La Paz, Baja California, Mexico
Escuela Superior de Ciencias Marinas, Ensenada, Baja California, Mexico
Nacional Hotelera, Ensenada, Baja California, Mexico
National Weather Service, San Diego, California, and Phoenix, Arizona
Naval Weather Service, San Diego, California
U.S. Coast Guard, San Diego, California

Ocean Education for the Public

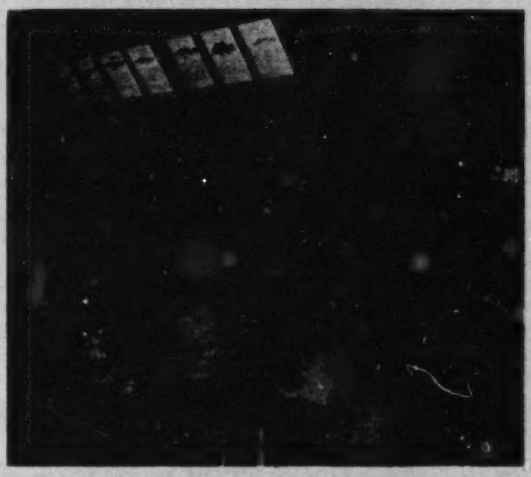
Donald W. Wilkie

The primary purpose of the work of the Aquarium-Museum at Scripps is to increase public understanding of the marine sciences through education programs and exhibits. Among its major achievements last year was the establishment of a new 20-foot tide pool, with rising and falling tides and wave action.

Education program

During the 1974-75 school year, 58,811 students visited the Aquarium-Museum in registered school groups.

A complete education package, written at five different grade levels, is sent to each class. It includes ecological information pertaining to intertidal organisms, as well as a guide sheet with questions to be answered during the field trip. The visiting classes are conducted by the 58 docents who are volunteer teachers trained by the Aquarium staff. The format of this education program has been utilized by many other aquaria, museums, and zoos. With Sea Grant support, it has been possible to hire a full-time educator to coordinate and administer the various programs and to prepare education materials.



Outreach program

Due to restrictions on bus transportation, more and more schools are unable to participate in field trips. Outreach docents travel throughout San Diego County, bringing marine specimens and a slide-illustrated lecture to these classes. An example is the pair of docents serving the Bonita area, who presented 40 hours of lectures to 1363 students at 11 schools.

Docents also provide an educational seashell program to area hospitals, including the children's wards at County Hospital, and the military wards of Balboa Naval Hospital.

San Diego-La Jolla underwater park guides

The Aquarium trains and organizes a special group of docents who act as underwater park guides to promote conservation. During the daytime low tide series, the guides, wearing Scripps jackets, patrolled the tide pools to answer questions and inform visitors of regulations governing park use.

Career experience program

Selected high school students who plan a career in marine biology or aquariology are trained in laboratory, classroom, and field work. Some are chosen from this group to be further trained as part-time aquarists and collectors for the Aquarium. Graduates of this program currently include several Ph.D.'s and an aquarist functioning at the professional staff level.

Summer courses

Classes in marine ecology are offered during the summer from the first grade level through high school. These courses were self-supporting through fees charged to participants.

Junior Oceanographers Corps (J.O.C.)

J.O.C. is a club for 4th graders through high school students. Monthly lectures by Scripps scientists explore marine biology and oceanography. Field trips included visits to ships, tide pools, a kelp-harvesting company, a tunaboat construction company, and an oceanographic cruise.

In-service training for teachers

Our Fifth Annual Symposium for Teachers was attended by almost 200 educators. "Earth Beneath the Sea" covered the current geology of the ocean basin by nine Scripps scientists.

Docent training program

A yearly lecture series in October is offered to train new docents, and as a refresher course for senior docents. Monthly meetings provide a question-and-answer forum, with additional upper-level lectures. Field trips were made to Scripps ships and local tide pools.

Advisory services

Advisory services are consistently requested by a wide variety of groups, including other aquaria and museums. Schools frequently request assistance in preparing education programs, while teachers often seek recommendations for books, slides, and films to use for marine sciences.

This past year assistance was given to the Waikiki Aquarium in Hawaii and the John G. Shedd Aquarium in Chicago in setting up educational programs. For three summers the federal program for underprivileged high school students (Upward Bound) has utilized our staff, books, films, and tanks for oceanographic instruction.

Spanish language programs

Our education program has been translated into Spanish because this is the primary language for many Californians.

"Project Amigos" is a local program which brings science winners from all the Mexican states to San Diego for a two-week stay. They profit from our bilingual program.

The local People-to-People organization helps support an oceanographic college in Ensenada, Baja California. Our docents act as guides and interpreters when the students and faculty of Escuela Ciencias Marinas visit Scripps' laboratories.

Publications

Aquarium—Article prepared for Encyclopaedia Brittanica.
Current status of some rarely exhibited fishes from the Gulf of California, presented at the American Association of Zoological Parks and Aquariums annual meeting in Philadelphia.
Education materials at five grade levels.
Scripps Aquarium coloring book.
Scripps Aquarium Newsletter.
The California Gray Whale - Film produced by National Parks Service. Script and editing by D.W. Wilkie.

Cooperating Organizations

CER, San Diego County Department of Education
Exploratory Career Experience Program, San Diego City Schools
Upward Bound, Federal program, San Diego, California

The new 20 ft tide pool at Scripp's Aquarium-Museum, La Jolla

EDUCATION

Education is an experience and opportunity that permeates all aspects of the Sea Grant program. Traditional classroom processes of teaching and learning are important but probably no more so than actual participation in inquiries into the understanding and meaning of natural, human and social phenomena. Our program is designed to provide opportunities for students at the graduate and undergraduate levels to undertake professionally guided inquiries addressing the solution of significant problems and learning the specialized techniques of scientific investigation.

Sea Grant Trainees

James J. Sullivan

Graduate students are an integral part of many Sea Grant projects. Meaningful completion of the projects with which they are associated can be used in partial satisfaction of their degree requirements. Accounts of independent research accomplished by these students during the 1974-75 grant year are reported under the titles of the research projects with which they were associated. Their complete reports are available from the Sea Grant Publications office (see note on inside back cover of this report).

The primary functions of the University of California are education and research. Public service is considered to be an extremely important auxiliary function. The purpose of the Sea Grant Act matches closely the purpose of the University, since it also calls for education and training, research, and public service. A major portion of the research of the University is carried on as an adjunct of the educational process, with graduate students carrying out the actual research under faculty guidance, with the dual purpose of performing a significant research project and satisfying the educational requirement of a master's or doctor's thesis. Many UC research projects were initiated by graduate students under the aegis of the faculty member listed as project leader of the research project. Many were initiated by a faculty member to carry out research in the area of his teaching; one or more of his graduate students have become involved in the project, have chosen a portion of it for their own thesis interests, and will carry the major responsibilities for completion. In other cases, students working on a Sea Grant project are acquiring the skills and experience that they will need in subsequent years in order to prepare and carry out their own thesis research. They are, therefore, the heart of the program and are acquiring their education as a primary function while performing useful applied research in marine resources as a public benefit.

Thesis project

A Sea Grant Trainee is expected to carry out a program of training and research leading to a recognized graduate degree. The program of work is arranged in consultation with a supervising faculty member and approved by the teaching department in which the student is registered. The program of research must be one that lies within the scope of the University of California Sea Grant College Program in order for a Traineeship to be awarded to the student. This means that, normally, the student will carry out a thesis project within one of the research projects proposed; in all other cases, the project must be approved by the National Office of Sea Grant as lying within its area of interest. A student maintains eligibility for a Traineeship by carrying out research diligently and making good progress toward completion of his thesis.

In 1974-75 there were 60 Sea Grant Trainees assigned to 31 projects on eight campuses funded by the UC program. They functioned in virtually all areas of research.

Practical Oceanography Training for Undergraduates

Richard F. Ford

Since 1970 San Diego State University has offered an experimental course in Practical Oceanography, which has been very favorably received as a career selection tool. The students who participated received first-hand experience with the techniques, rigors, and technical difficulties of conducting scientific work at sea, as well as practical experience in a variety of research projects on shore.

Since 1970 San Diego State University, in cooperation with the Scripps Institution of Oceanography, has offered a one-semester, experimental course in Practical Oceanography (Oceanography 400). The course was designed to provide both practical training and career orientation for undergraduate and beginning graduate students in the marine sciences.

The course was again offered to a group of five San Diego State University students during the Spring Semester of 1975. As in previous years, George T. Hemingway of the Scripps Institution of Oceanography served as coordinator and primary instructor for the course. Students selected from a large number of qualified applicants were enrolled for the six unit course at San Diego State University and employed as assistants at the Scripps Institution of Oceanography.

Students were selected from the disciplines of biology, botany, chemistry, geology, engineering, microbiology, physics, and zoology. Information concerning the numbers of students in each major discipline involved in the five year history of the course is summarized in Table 1. Because marine science is inherently multidisciplinary, oceanographic cruises are generally cooperative efforts involving scientists from a variety of disciplines.

Students were selected on the basis of good academic achievement and sound, basic preparation in the sciences and mathematics. They received first-hand experience with the techniques, rigors, and technical difficulties of conducting scientific work at sea, as well as practical experience in a variety of research projects on shore. The program has made effective use of the unique capabilities of the Scripps Institution staff and facilities.

TABLE 1. Major Fields of Students Accepted into the Practical Oceanography Program, 1970-1975

Major Field	Number of Students
Life sciences	26
Chemistry	3
Geography	1
Geology	3
Engineering	1
Physics	2
TOTAL	36

Seminars and discussion groups were provided by the faculty and staff of the Scripps Institution of Oceanography and San Diego State University, both ashore and at sea. Topics included plant chlorophyll and phytoplankton productivity, phaeophytin, nutrient chemistry, zooplankton distribution and abundance, vertical and horizontal distribution of temperature, oxygen, and salinity in the upper waters of the world oceans, density distribution, geostrophic flow, wind driven circulation, hydrographic data processing, thermometer calibration, zooplankton biomass processing, and radioactive element tracing.

Scientific work at sea

Shipboard experience varied from one semester to another, depending upon ship operating schedules, but averaged 28 days per semester. The specific techniques to which students were introduced at sea included Nansen bottle casts and thermometry, salinity and dissolved oxygen determinations, hydrographic data summarization, nutrient analyses, net tow and trawling operations, specimen processing, weather and sea state determination, buoy mooring and servicing, small boat operations, and general seamanship.

As part of the course work, each student prepared from one to 11 seminars per semester for presentation to his classmates, covering various aspects of marine chemistry, physics, biology, geology, and geography. Each also selected a library research project on a topic dealing with marine sciences, which was presented to the class. During the latter part of each course, students worked half-time for four to six weeks with a scientist or research group at

TABLE 2. Summary of the Present Status of Students Participating in the Practical Oceanography Program, 1970-1975

Status	Number of Students
Employed at the technical level in marine or allied sciences	9
Employed at the professional level in marine or allied sciences	3
Medical technician	1
High School teacher	1
Continuing undergraduate work	2
Continuing graduate work in the following degree programs:	
M.A. or M.S.	7
Ph.D.	3
M.D.	1
D.V.M.	2
D.D.S.	1
Status unknown	6
TOTAL	36

the Scripps Institution of Oceanography, San Diego State University, or the National Marine Fisheries Service. The students each also spent 40-80 hours in processing hydrographic data.

This course experience provided an effective, sometimes painful, opportunity to evaluate the marine sciences as a career. The students, including those who decided not to continue in the field, were unanimous in their support of the internship approach employed in this course as a career selection tool.

Tables 2 and 3 provide information on the current academic and employment status of the students who participated in the program. The large proportion of students who are continuing in graduate school may indicate that the grade point cut-off we employed in the selection process was too high for a technologically oriented course.

TABLE 3. Highest Degree Attained by Students Participating in the Practical Oceanography Program, 1970-1975

Highest Degree	Number of Students
A.B./B.S.	29
M.A./M.S.	5
Ph.D.	2
TOTAL	36

Cooperating Organizations

Scripps Institution of Oceanography, La Jolla, California

RESEARCH

Although education and public service are essential aspects of the Sea Grant College Program, the ultimate and sustained viability of the Program rests on the quality and meaningfulness of the research.

Historically California has been recognized as a leader in many fields of academic research. Unique professional competence related to Sea Grant's areas of interest is scattered throughout the state on campuses of the University of California system, the State University system, and some private universities. The research reports that follow issue from all of these sources. Sea Grant projects funded by the University of California Sea Grant College Program have been rigorously reviewed at the University, State, and National levels and have survived competition with many other proposed projects. While conduct of individual projects is the responsibility of each investigator, overall program coordination provides opportunities for research participants in each of a number of subject areas to meet and exchange information and ideas with other researchers in related investigations. Increasingly scholars from several academic institutions, agencies, and disciplines are combining their talents to seek solutions for problems of identified importance. Also, increasingly planning for future research is being guided by the collective advice of investigators meeting in subject area conferences to consider the current state of knowledge in their fields and the directions that new research should take.

The 1974-75 University of California Sea Grant research program has been categorized in subject areas dealing with Coastal Resource Issues, Aquaculture (plant and animal), Fisheries, New Marine Products, and Energy Resources. An additional category entitled "Rapid Response" has been established for projects designed to respond to newly identified and urgent research needs and to provide for early exploration of new concepts.

COASTAL RESOURCE ISSUES

Nowhere are the conflicts between the activities of man and the values of nature more starkly delineated than along the coastal boundaries of the nation.

In recognition of these conflicts and the potential for irreversible damage to public values, the California Coastal Zone Conservation Act of 1972 mandated delivery of a comprehensive coastal plan to the legislature by December 31, 1975. As a result this has been a year of intensive effort to assist coastal planners and ultimately the legislature in preparing a wise and implementable plan for legislative consideration.

Many investigators in this subject area have provided extensive advice, guidance, and information on public policy and technical matters to the California Coastal Zone Conservation Commission in addition to pursuing the specific objectives of the Sea Grant projects which are covered in the reports that follow.

Not all of the projects relate specifically to the California Coastal Plan but are oriented toward establishing a firm base for future resource management in the shore and nearshore area and toward safe recreational utilization of coastal waters.

Predictive Methods and Information Systems to Assist Coastal Zone Management Programs

Robert Twiss

On November 7, 1972, California embarked upon an innovative four-year experiment in coastal zone management. The date marks the passage of the state ballot initiative creating the California Coastal Zone Conservation Commission and mandating the development of a Coastal Plan. The Coastal Commission's strong regulatory powers and unique policy development process have attracted nationwide attention.

For review purposes our work program of 1974-1975 can be divided into four areas of activity, each intended to provide direct assistance to the California Coastal Zone Conservation Commission (CCZCC) and to develop methods applicable to other states engaged in Coastal Zone Management programs. Our involvement with the CCZCC dates from shortly after the organization of their planning staff in February 1973. We have dealt primarily with the state level commission staff.

Our primary activity has been the development of a process that could be employed by local units of government to prepare coastal plans based on the policies adopted by the CCZCC. One case study has been used to develop the process—the Half Moon Bay area of San Mateo County.

For use by local governments

Extensive data on environmental factors, resources, land use, public service systems, property ownership, and assessed valuation were collected and analyzed in context with the proposed and adopted Coastal Commission policies. The data collection enabled the research team to develop a series of analytic steps that local governments could use to apply and evaluate the CCZCC policies in a plan making context. Case studies conducted by the Coastal Commission staff in Huntington Beach and by USC Sea Grant in Marina Del Rey were used to test the transferability of the analytic steps to all local units of government within California's coastal zone. A report is near completion that describes the step-by-step process that local governments should use in developing a coastal plan that conforms with the Coastal Commission's policies.

The data and analyses conducted in the Half Moon Bay area, in addition to developing a process for preparation of local plans, were used to test the applicability of many key Coastal Commission policies. Several policies were revised by the Commission to resolve application problems revealed by the case study analysis. As examples, we may quote the policies regarding protection of prime agricultural lands and concentration of residential development in urban coastal areas. An especially important product of the development and testing of the process in the case study was the input which the study team was able to make in substantially revising the coastal zone management boundary and required content for local coastal plans. Another product of the case study was the projection of land use alternatives that could be used to assess the potential fiscal impacts on local units of government if the CCZCC policies are implemented.

A process for assessing the local fiscal impact of implementing CCZCC policies is being developed by another Sea Grant project (George Goldman, Cooperative Extension, UCB) using the outputs of the Half Moon Bay case study.

The second major activity of the project was the design and application of a methodology to identify and inventory the inland extent of California's coastal scenic resource. The Coastal Commission specifically requested that Sea Grant Rapid Response funds be allocated to this activity. To delineate the inland extent of the coastal scenic resource was of particular importance to the CCZCC as a criterion for defining the inland limit of the coastal zone. The research team developed a methodology, mapped the inland extent of coastal scenic resources, and prepared a report describing the entire process ("Identification and mapping of California's coastal viewshed corridor").

A third activity of the year's research work was a case study analysis assessing the economic impacts of park acquisition and development. The case study area was the Smith River-Lake Earl region of Del Norte county and was an outgrowth of a Sea Grant Rapid Response project conducted by the Graduate School of Public Policy (UCB).

Extension of the coastal zone management library developed during the past three years was the fourth activity. The library, which now includes over 1500 documents and 2200 citations, has been used by the staff of the Coastal Commission, coastal interest groups, and students. A second edition of the coastal zone bibliography, containing citations from documents in the library plus citations from other coastal zone information centers, has been prepared ("Coastal Zone Bibliography: Citations to documents on planning resources management and impact assessment").

Two directories on state and federal responsibility in the California coastal zone were published during the year. The directories are arranged according to topic headings (e.g., wetlands, oil and gas extraction). Each of the 38 topics is divided into four categories to describe the various aspects of an agency's responsibility. These categories are: administration and advisory services; regulatory actions; functional responsibilities; and research programs and information collection. Titles of the two reports are: "Federal involvement in the California coastal zone" and "State involvement in the California coastal zone."

Publications

Ashbaugh, J., and J. Sorensen, Identifying the public for participation in coastal zone management, *Coastal Zone Management Journal*, vol. II, No. 3.

Gamman, J., S. Towers, and J. Sorensen, Federal involvement in the California coastal zone: A topical index to agency responsibility, November 1974. Sea Grant Publ. No. 29, IMR TR-42.

Idem, State involvement in the California coastal zone: A topical index to agency responsibility, May 1975. Sea Grant Publ. No. 42, IMR 75-7.

Sorensen, J., The California experience, *In* Recreation in the Coastal Zone, Proceedings of a conference sponsored by the Bureau of Outdoor Recreation, Southeast Region, March 1975.

Cooperating Organizations

California Coastal Zone Conservation Commissions, Eureka, San Rafael, Santa Cruz, Santa Barbara, Long Beach and San Diego, California

Methods for Determining Physical Changes of Southern California Coastal Lagoons

Richard Phillips

Methods have been developed for determining the ecological conditions in the lagoons and estuaries by studying the type of sediments deposited, the vegetation, the associated foraminifera and pollen. Reliable dating techniques using pollen and lead content have been devised.

The Environmental Studies Laboratory of the University of San Diego has been engaged in an interdisciplinary program to develop reliable methods of determining and tracing recent changes of conditions and shorelines within the coastal lagoons of San Diego County. This program, in cooperation with the California State Lands Commission, has included archaeological, historical, geological, chemical, and biological investigations.

Direct physical or historical evidence of changes

Shell and animal material from the Indian middens that have been excavated near lagoons were analyzed, mostly from faunal lists already available. Dr. James Moriarty concludes that most of the lagoons were open to the ocean most of the time with normal salinities and tidal ranges during the period of Indian occupation. Spanish and Mexican government documents and diaries of the explorers offer clear evidence that early land use patterns had little effect on the lagoons up to the time of the American Period. In the 1880's a marked change in the environmental conditions of the lagoons appears related to the introduction of agriculture adjacent to them and the construction of railroad structures across them.

A study of historical maps and their accuracy has been conducted by the California State Lands Commission. While their final report is not yet available, the preliminary findings indicate that the upper portions of the lagoons have been quite stable, unless modified directly by man. This conclusion is borne out by a study of aerial photographs taken from 1928 to the present. Detailed analysis of these photographs indicates that, in many instances, even small features have been stable for almost 50 years.

Dating techniques

The time span of interest in this study has been too short for accurate application of radio-carbon dating; thus, alternative methods were sought. The decomposition of organic pigments in the sediments through time was investigated. This proved too cumbersome for routine work, but did indicate that vertical mixing of the marsh sediments by biological activity was much less than we had feared. Mercury is a common trace element in coal. Two distinct peaks of mercury distribution with depth have been found in some cores. The deeper of these can be tentatively identified as the time of coal-burning railroad operation across the lagoons. The high concentration at or near the surface probably reflects the introduction of mercury from agricultural fungicides in the watershed of the lagoon. While these results are interesting in their own right, and should be followed up with more complete study, complications introduced by sediment type and organic activity make them too unreliable as simple dating techniques.

Previous studies have shown that areas of slow sediment accumulation have an abnormal concentration of lead in the sediments deposited since the introduction of tetraethyllead in motor fuels. A method was derived to analyze for the relative abundance of lead in the marsh sediments. This analysis indicated that relatively undisturbed sediments show a larger increase in lead content near the surface.

Many plants produce a pollen that is very resistant, and can be identified in sediments. A major effort was directed toward the isolation and identification of the pollen of non-native plants for which the date of introduction is known. Two types of pollen have proved to be useful, Eucalyptus and foreign conifer. Both produce an abundant pollen that is easily recognized. Eucalyptus trees were introduced into San Diego in 1875 and were extensively planted in the coastal areas. It is reasonabe to expect the pollen to appear in sediments younger than about 1880. The appearance of non-native pine pollen in the sediments seems to correspond with the time of residential build-up around

the marsh in question. For instance, a sharp increase in non-native pine pollen in the Mission Bay Marsh seems to mark the residential development of Pacific Beach about 1925.

Methods of determining the ecology of the lagoons

The pollen of native plants isolated from the sediments offer a valuable source of information as to the environment of the lagoons at the time of the sediment deposition. This study has been carried out in parallel with the study of introduced pollen. Peta Mudie concluded from an analysis of the pollen data that salt marsh pollen assemblages can be distinguished, and they appear to provide reasonably sensitive indicators of changing environmental conditions. In southern California lagoons, a close correlation exists between the elevation of the sediment at the time of deposition and the pollen spectrum.

David B. Scott studied the distribution of the microscopic single-celled animals, the foraminifera. He concluded that foraminifera are extremely useful in determining changes in the environment in marsh stratigraphy, and that there are definite assemblages that can be associated with different elevation ranges in the marsh.

Studies of other microscopic forms, especially the ostracods and diatoms appear to be useful. These studies are continuing, and no definite conclusion can be stated at this time.

Detailed studies of the vegetation, with special emphasis on differences in plant communities in stable and disturbed areas, and of changes relative to elevation have been completed. The United States Army Corps of Engineers has been most helpful in these studies by making the results of their recent surveys in the lagoons available before publication of the data. The studies indicate that vegetation is a sensitive indicator of tidal conditions and ground elevation and these differences can be noted on aerial photographs, particularly modern high-resolutions photos.

The study of the larger animals, especially shellfish, that inhabit the lagoons has been somewhat disappointing. While open lagoons show a high diversity of specimens, the tidal action causes the resulting shell accumulations to be very mixed. In closed lagoons, the environment prevents the shells from accumulating, as the calcium carbonate of the shells is quickly dissolved.

Detailed sedimentary analysis has been completed, with samples taken from many different environments. Distinct environmental differences have been noted, and these can be used in correlation with other methods to determine the environment of deposition of the sediments. Sediment type mapping in areas of known change has been very useful. Further analysis of the data is necessary to conclude the general application of this type of approach.

Holes were drilled through the fill that has been placed over the marsh land of the Del Mar Lagoon to determine if the environmental conditions that existed at the time of the filling could be determined. These holes showed that the emplacement of fill in the areas tested did not disturb the underlying surface, and that the environmental indicators were well preserved in the marsh sediments.

In general, the field work has been completed, and most of the data analyzed. At present, compilation and preparation for publication are under way.

Much of the research mentioned above was significantly aided by students taking part in the National Science Foundation Undergraduate Research Participation Grant to the Environmental Studies Laboratory. In addition, resources and advice were available from Scripps Institution of Oceanography, San Diego State University, the California State Department of Parks and Recreation, and the City of Del Mar.

Publications

Mudie, P.J., Palynology of recent coastal lagoon sediments in central and southern California. Paper presented to the 70th Annual Meeting of the Botanical Society of America, Corvallis, Oregon, 1975.

Scott, D.B., Quantitative studies of marsh foraminiferal patterns and their application to recent stratigraphical problems. Paper presented to the Fellows of the San Diego Society of Natural History. Presented for publication, Benthonics '75 symposium, Delhousie University, Halifax, Nova Scotia, Canada, 1975.

Scott, D.B., P.J. Mudie, and J.S. Bradshaw, Benthonic foraminifera of three southern California lagoons: ecology and recent stratigraphy, *Jour. of Foraminifera Research*, 6(1), in press.

Cooperating Organizations

State of California Division of Parks and Recreation, San Diego
California State Lands Commission, Sacramento
San Diego State University, California
Scripps Institution of Oceanography, La Jolla, California
The City of Del Mar, California

Diving Safety Research Project

Glen H. Egstrom

The Diving Safety Project at UCLA is concerned primarily with fostering conditions for safe and effective diving through improvements in training, equipment, environmental adaptation, stress adaptation, working capacity, biomechanics and emergency procedures.

This project has evolved from an intensive study of underwater work performance which was begun in 1965. These performance studies revealed the remarkable specificity of the skills used in diving with respect to the variability of environmental conditions. The nature of the preparation necessary to make a safe, effective adaptation to a given task under given conditions was not generalized but rather highly specific. The Diving Safety Project was designed to take advantage of the expertise and resources developed in previous studies and apply them to the problem of safety in the recreational diving field. NOAA has estimated that there are about 191,000 active sport divers in the U.S. in 1974. This population which operates in less than 200 feet of seawater, has never had its rather unique problems studied in any systematic fashion. There has been a general lack of awareness of the nature of the calculated risks involved in sport diving. The UCLA Project proposes to meet the following objectives:

To improve the understanding of the requirements for safe, effective diving through the evaluation of systematic research efforts. The areas of study are: training, equipment, environmental adaptation, stress adaptation, working capacity, biomechanics and emergency procedures.

To develop criteria, instrumentation, and methodology for the objective evaluation of the critical parameters of recreational diving.

To work closely with organizations and agencies whose objectives and/or responsibilities are directed at the problems of diving safety and education.

The research program consists of four interacting areas of study.

1. The biomechanical analysis of current scuba diving practices is being undertaken in order to evaluate their efficiency and effectiveness. This analysis includes surface swimming, underwater swimming, buddy breathing, emergency inflation of flotation devices, weight belt utilization, buoyancy control techniques, aiding distressed divers, entries and exits, and other critical diving skills. Biotelemetry equipment and automated depth time profilers have been developed to aid in this analysis. Cinematographic analysis techniques are being coupled with physiological measurement techniques to determine relative efficiency and effectiveness for comparative purposes. Current "rules" for the conduct of these skills are being tested against the results of the analysis in order to determine the effectiveness of the rules.
2. Recent work in our laboratories has led to strong reinforcement of the concept of state dependency upon diving behavior. It appears obvious, therefore, that additional evaluation of the effectiveness of various training techniques is needed. At present we have little objective information relating to the amount and type of training needed before an individual reaches a competency level which can be associated with safe, effective diving. The development of learning curves for critical skills in diving behavior is a necessary prerequisite to establish learning curves for performance under a variety of environmental conditions in order to develop criteria for "overlearned" achievement levels. Reinforcement schedules are an additional parameter which will be examined to determine the "decay" rate of the learned skills.
3. The effect of equipment and its function upon diving performance under various circumstances has not been well identified. We are establishing functional criteria for various items of diving equipment that are concerned with safe, effective performance. These criteria are being developed to use as a basis for the evaluation of current diving equipment. For example, the ventilation and resistance criteria are being identified and breathing devices are being measured to determine inhalation and exhalation characteristics during the breathing cycle at various rates (10-150 l/min), tidal volumes (2-4 l), water depths (0-200 ft) and temperatures (30-75°F). Preliminary data revealed a much wider range of variation than anticipated as a function of changes in respiration rate alone between five and 30

breaths per minute. This variation would appear to be compounded by changes in gas density as a function of depth and temperature. This variation might very well be a factor in diving accidents which occur underwater while the diver is exerting himself in trying to solve a problem. Major changes in regulator design are now under way and these devices will be evaluated as they come onto the market.

4. Critical paths of behavior in diving emergencies will be identified and catalogued. Alternative methods for resolving the emergencies will be developed and analyzed for relative effectiveness. The techniques for gathering these important data are currently under development as a function of the three previously identified areas.

Publications

A report on project activities was sent to over 300 agencies, companies and diving educators across the U.S.A.

Diver Training, a paper presented at Tokyo Medical University, meeting of Diving Technology Panel appointed by U.S. Department of Commerce.

Cooperating Organizations

Commercial Diving Center, Wilmington, California
Diving equipment manufacturers:
- AGA Corporation, Foster City, California
- AMF Voit, Santa Ana, California
- Aqua Craft, San Diego, California
- Dacor Corporation, Chicago, Illinois
- Farallon Industries, Belmont, California
- O'Neil, Inc., Santa Cruz, California
- Parkway-Poseidon, Perth Amboy, New Jersey
- Scuba Pro, Paramount, California
- Sportsways, Inc., Paramount, California
- Sub Aquatic Systems, Redondo Beach, California
- White Stag, Inc., Marina Del Rey, California

Diving Equipment Manufacturers Association, Long Beach, California
Leonard Greenstone Company, Los Angeles, California
Los Angeles County Department of Beaches
Los Angeles County Department of Parks and Recreation
National Association of Underwater Instructors, Colton, California
Naval Medical Research Institute, Behavior Sciences Department, Bethesda, Maryland
Undersea Medical Society, Rockville, Maryland
U.S. Navy Experimental Diving Unit, Panama City, Florida

Physical Criteria for Coastal Planning

Douglas L. Inman

To lay the basis for rational coastal planning, a data acquisition system has been developed that makes accurate physical measurements of waves, currents, thermal fluctuations and sediment movement in the nearshore environment.

The only rational basis for coastal planning is from a complete understanding of the physical processes active in the coastal environment. This project has been directed toward the development of a data acquisition system for making the accurate physical measurements necessary to understand these processes. This effort has resulted in the development of the Shelf and Shore (SAS) data acquisition system for use in the nearshore environment. Over the past several years the SAS system has been used to make measurements of waves, currents, thermal fluctuations, and sediment movement which provided the basic data to understand many of the significant physical processes. This information is then used in the formulation of practical planning criteria for the coastal zone.

SHELF AND SHORE (SAS) SYSTEM

The SAS system developed by this Sea Grant project has been used extensively to gather data from the nearshore environment. Two major improvements have been made in the system during the past year: (1) The bottom section of the shelf station has been redesigned to improve the underwater cable connections; and, (2) a new electronics package has been designed to attain more accurate data transmission. The redesign of the cable connections has proved extremely successful and greatly improved the reliability of the system. The new electronic package incorporates a higher accuracy analog to digital converted (12 bits instead of 10 bits) which not only increased the data accuracy, but also reduced the power consumption of the station by 20 per cent.

During the past year as many as five shelf stations were deployed to support various experiments undertaken by the group.

Torrey Pines station

A shelf station has been deployed off Torrey Pines Beach, approximately 3 kilometers north of Scripps Institution of Oceanography for over three years. This station is 900 meters seaward of the beach at a water depth of 10 meters. It is

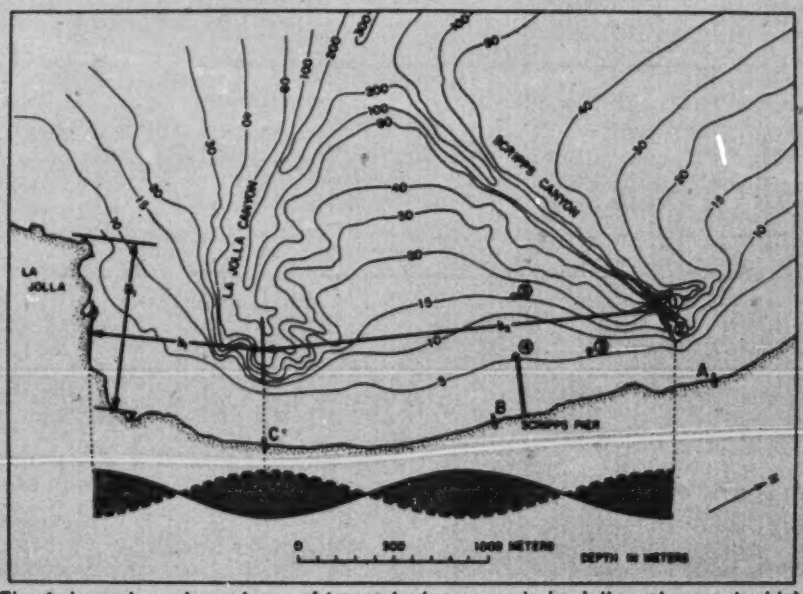


Fig. 1. Longshore dependence of trapped edge waves in La Jolla embayment which are presumed to drive strong currents in the submarine canyons. The schematic edge wave shows the positions along the coast of amplitude nodes and antinodes; the latter are also points of maximum run-up. Circled numbers and letters indicate measurement sites

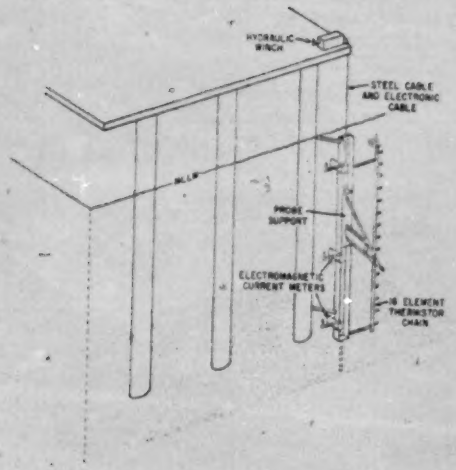


Fig. 2. Experimental apparatus to measure the thermal structure as presently installed at Scripps Pier. For the proposed measurements, an array of multiple, small thermistors will be mounted on the probe support

equipped with three absolute pressure sensors arranged in a line array parallel to shore and with two accelerometers for measuring wave energy and direction. The wave field is measured for a one-hour period four times a day in order to provide the data necessary for compiling a local wave climate. To date approximately 2200 data series have been obtained from this installation.

Shelf station array

Figure 1 shows the location of four shelf stations placed in the vicinity of Scripps Canyon for the study of canyon currents. A shelf station was installed at Site 2 in the canyon head at a depth of 20 meters and equipped with an electromagnetic current meter, pressure sensor, and accelerometers to measure canyon currents and waves. Other stations were placed at Sites 3, 4, and 5 to make environmental measurements in association with those in the canyon. Synoptic measurements were made from these instruments at various times under different environmental conditions for continuous recording periods of up to 16 hours. Data were reduced and analyzed with a minicomputer system that is part of the shore station.

Scripps Pier

The installation at the end of Scripps Pier in 5 meters of water has been used to measure temperature fluctuations and currents associated with internal bores. The sensor configuration included a two-element thermistor chain; a temperature profiler; three electromagnetic current meters; and, wind speed and direction sensors. Approximately 150 hours of continuous data were obtained from these installations. The temperature profiler is shown in Fig. 2 and consists of a steel structure which serves as a track for an instrument package. The instrument package is hoisted through the water column by a winch which is located on the pier deck. Instrumentation on the package presently consists of small time constant temperature sensors, although in the future it is planned to mount electromagnetic current meters which are sensitive to currents in a horizontal plane. The temperature sensor is connected via the SAS system hardware to a minicomputer in the Shore Processes Laboratory. The nonlinear output from the thermistor is deconvolved into temperature, and a real time plot of the temperature as a function of depth is displayed on a CRT display terminal.

STUDIES OF THERMAL FLUCTUATIONS IN COASTAL WATERS

Internal tidal bores

The thermal sensors located at the end of Scripps Pier have been used to make measurements of internal tidal bores in shallow water. A typical sequence of temperature profiles taken at 40-second intervals is shown in Fig. 3. Successive profiles show how rapidly the temperature profile changes when an internal bore progresses into shallow water. These internal bores have great significance with regard to the overall thermal structure and mixing of coastal waters.

Vertical structure of coastal currents

A vertical array of four equidistant current meters was used to measure horizontal currents in 18 meters of water at the NUC Tower in San Diego. The instruments were sampled for a period of 33 days in late summer 1974, resolving frequencies up to 15 cph. Onshore (EW) and longshore (NS) currents are found to be essentially uncorrelated at all depths over the period of the measurements. Longshore currents exhibit significant coherence with the surface tide, and the effect of a southerly wind disturbance lasting over three days is noticed as a northbound current which is most intense near the surface. Longshore currents do not exhibit significant coherence through the water column other than at the tidal frequencies. The spectra of onshore currents exhibit a peak at the semidiurnal frequency corresponding to internal tides as well as a second lower, but broader, peak at frequencies between 1 cph and the buoyancy frequency. Onshore current amplitudes

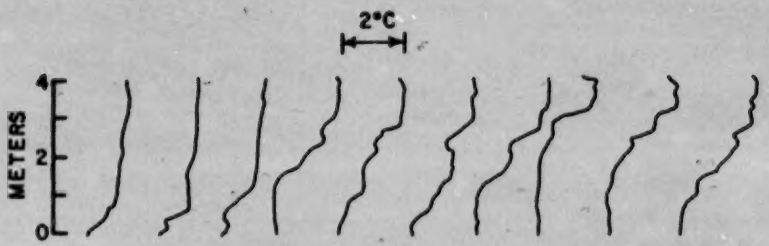


Fig. 3. A sequence of temperature profiles taken from 0 to 4 meters above the bottom at 40-second intervals at the end of Scripps Pier. Note the rapid change in the vertical temperature structure which is due to the internal bore

corresponding to the internal tides are on the order of 10 cm/sec, while the higher frequency fluctuations have amplitudes on the order of 3 cm/sec. Significant coherence exists between all measurements of onshore current with a phase shift of π between surface and bottom currents. The onshore current measurements are consistent with the mode 1 oscillations of a three-layer model consisting of homogeneous surface and bottom layers separated by a layer having constant buoyancy frequency.

WAVE CLIMATE

Wave records have been taken four times a day at Torrey Pines Beach since February 1973 with the use of a shelf station and a linear array of pressure sensors. The array is at a mean depth of 10 meters and is roughly parallel to the bottom contours. The data are transmitted by radio link to a shore station.

The wave records are used to compute estimates of the frequency and directional spectra of the wave field. The significant peaks of the frequency spectra are selected and then characterized by their bandwidth, energy, and frequency of maximum energy density. Consideration of the spectra in terms of the significant peaks aids in the association of the energy with various wave generating disturbances. Using this technique of analysis it has been established that the narrow, low frequency peak with southerly directions, which is persistent in the wave records during the months of May through October, is generated by tropical storm activity in the Eastern North Pacific. Evaluation of typical wave characteristics that are generated by such storms, and the other types of wave-generating disturbances such as North Pacific cyclones, will provide a good understanding of wave climate. A computer technique has been developed which selects the significant spectral peaks using both frequency and directional information. This has allowed both the data reduction and analysis to be performed entirely by computer.

The number of pressure sensors in the line array was reduced from four to three in the fall of 1974. A study was made to optimize the array spacings and specifications of data sampling. The adjustments to the array design and sampling techniques were made with consideration of frequency resolution, high frequency cut-off due to depth attenuation of the pressure field, aliasing of the directional spectrum, and directional resolution. The length of the array was slightly increased from 92 meters to 99 meters, although the array was left in 10 meters of water. The sampling rate was decreased to 2 samples/sec to afford better frequency resolution. The data from this smaller version of a line array will help evaluate the performance of limited systems.

WAVE FORCES ON SUBMERGED SPHERES

A laboratory investigation of wave-induced forces on submerged spheres and the associated local flow was conducted in an effort to unravel a portion of the poorly understood problem of predicting wave loads. Learning more about the basic mechanics behind this problem is of special interest to evaluating the performance of the tilting spar shelf station. In addition, previous studies have produced a number of unexplained results. Resistance coefficients for spheres have not clearly demonstrated systematic variations with dimensionless scale parameters, and many values appeared to be anomalously small or large with no apparent physical explanation.

The horizontal wave loads were measured for polished spheres of 10 cm and 20 cm diameters subjected individually to single frequency waves of 0.2 to 0.75 Hz and heights of 5 to 20 cm, for a total of 32 separate experiments. All experiments were

conducted with the spheres at mid-depth in the 1.5 meter deep wind-wave channel in the Scripps Institution of Oceanography, Hydraulics Laboratory. The resistance coefficients were evaluated in the frequency domain using harmonic analysis techniques. The local flow was studied by means of flow visualization using dye injection from three ports embedded in the spheres at 90° increments along the median plane.

It was learned that the local flow possessed a net circulation in the sense of rotation of the orbital motion. In addition, the local flow was not observed to separate, being confined by small particle orbits to the immediate neighborhood of the sphere, provided the sphere diameter exceeded the orbital diameter. These two features distinguish the orbital wave induced motion from other classes of oscillatory flow.

The drag coefficients measured in this investigation were found to vary systematically with the inverted Strouhal number, as shown in Fig. 4. At small values of Strouhal number for which the orbital diameter was on the order of 1 cm, the sizes of the drag coefficients were typical of those for unseparated steady unidirectional flow found at low Reynolds number. At Strouhal numbers above 6.0 for which flow visualization confirmed separation, the drag coefficients were comparable in size to the classical values for steady unidirectional flow at an equivalent Reynolds number.

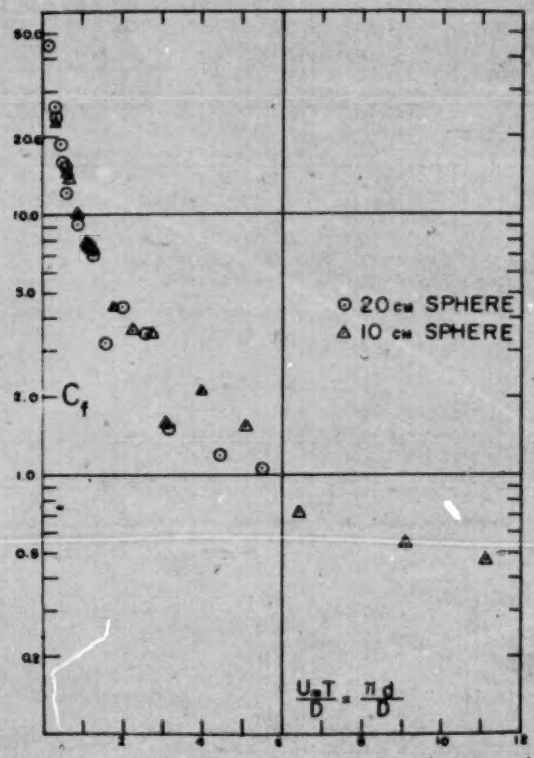


Fig. 4. Drag coefficient, c_f, for spheres as a function of the Keulegan-Carpenter form of the Strouhal number $u_m T/D$, where u_m is the maximum horizontal component of the orbital velocity, T is the wave period, and D is the diameter of the sphere

The inertial coefficients were found to correlate best with the scattering parameter, kD/2, as shown in Fig. 5. It was surprising to find that all of these values are less than unity, since this is theoretically impossible for such a flow problem involving a small body in an accelerating fluid. However, the observed circulation implies the existence of a lift force, which by the Kutta Joukowski theorem, can be shown to have a component which is in phase with and opposes the horizontal component of the inertial force. Thus, it was learned in this study that water waves do not diffract like acoustic plane waves for a sphere whose size is very small in relation to the wave length. Furthermore, the wave force estimator (Morison's Equation) must be modified to account for wave-induced lift.

DISSEMINATION OF INFORMATION

Sea Grant Conference on Physical Variables in the Coastal Zone

One of the objectives of this project is to disseminate the information obtained from the data collection and study aspects of the project to potential users. In order to fulfill this objective partially, a Sea Grant Conference on Physical Variables in the Coastal Zone was convened at Scripps Institution of Oceanography on 31 March - 1 April, 1975. Representatives from many Sea Grant Colleges in the United States were invited to attend and participate in discussions of the physical processes in the nearshore environment.

The conference centered on recent developments in the measurement and evaluation of significant physical parameters pertaining to waves, currents and the transportation of sand in the nearshore environment. Discussions during the meetings brought out a highly beneficial exchange of ideas on this topic and was most helpful to all in attendance. Success of the conference has also been verified in post-conference communication with participants in that some of the data acquisition and analysis technology developed under this project has been adopted by other users. In addition, the usefulness of this initial conference has led directly to the organization of a second such Sea Grant Conference on coastal engineer-

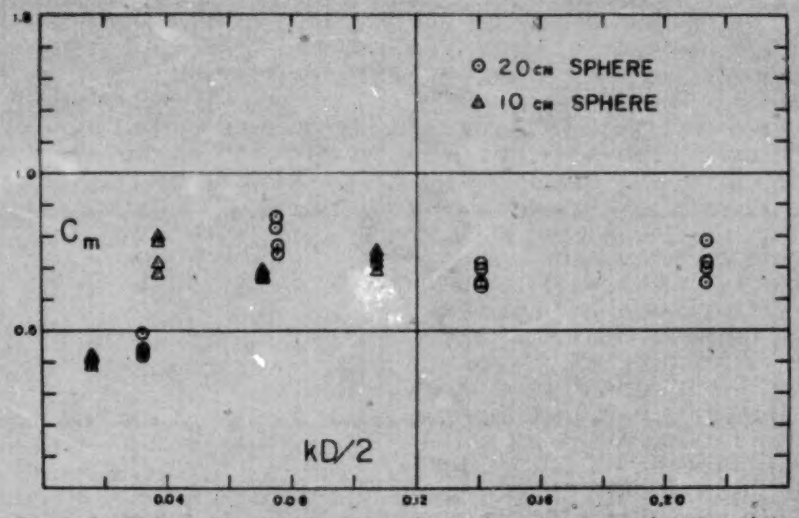


Fig. 5. Coefficient of inertia (virtual mass), c_m, for spheres as a function of the scattering parameter, kD/2, where $k = 2\pi/L$ is the wave number, and D is the diameter of the sphere

ing, which was held at the University of Florida on 19 November, 1975.

Other dissemination of information to users

During the past year members of the Shore Processes Study Group with Sea Grant support have met with numerous people on an individual basis to discuss specific problems. Most notable of these were meetings with representatives of the California Coastal Zone Commission, California Department of Navigation and Ocean Development, San Diego County, and several private industrial corporations.

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Cooperating Organizations

State of California
- Assemblyman Kapiloff (78th Assembly District)
- Department of Navigation and Ocean Development
- California Coastal Zone Commission
- San Diego Coast Regional Commission

San Diego County - Department of Sanitation and Flood Control, California

Southern California Edison Company, Los Angeles, California

Dravco Corporation, Pittsburgh, Pennsylvania

An Oceanographic Inventory of the Southern California Shelf Sand and Gravel Deposits

Peter J. Fischer and Richard W. Berry

An assessment of sand and gravel resource potential of the southern California shelf is nearing completion. The study extends from the Mexican border north to Point Conception, a distance of 460 km. Based upon preliminary estimates, the volume of unconsolidated shelf sediments is 26.5 km^3. Economic studies are now in progress in association with Meade (UCSB) to determine which, if any, of these deposits are viable resources.

Offshore sand and gravel deposits were mapped using acoustic or seismic reflection techniques and an historical (1946-1960) data base of core-hole information donated by industry. During the past year over 1200 km of high-resolution seismic profiling was completed off San Diego, Orange, southern Los Angeles, Ventura and Santa Barbara Counties. Using these profiles in conjunction with industry core-hole and seismic information, a series of shelf maps by county are in progress or in press. For coastal planners these maps depict resources as well as hazards. In addition to sand and gravel deposits, geologic structure (faulting and uplift) and gas and oil seeps are shown.

For Santa Barbara County the basic data, sand and gravel, geologic structure and gas and oil seep maps are complete. Publication of these maps by the California Division of Oil and Gas is in progress. Maps of southern Los Angeles, San Diego, Orange and northern Ventura Counties will be completed during the current year, but the southern portion of Ventura County will not be finalized until 1977.

Off the Santa Barbara County shelf, sand and gravel deposits occur as buried stream channels or prisms of sediment wedged against ancient sea cliffs. These deposits are truncated by later Holocene (?) erosion over structurally controlled topographic highs. Thick channel-fill deposits are found off Pt. Conception, Gaviota, Coal Oil Point and Santa Barbara. The mixture of grain sizes in these deposits makes them most suitable for industry utilization.

Off Coal Oil and Goleta Points, a net loss of unconsolidated shelf sediments during the past 30 years is indicated by repetitive data dating from 1946 to the present. Scouring by bottom currents has locally stripped up to seven meters of fine sand and silt from the middle and outer shelf. Bottom current measurements indicate that this material was transported southwest into the basin trough. These exceptionally high erosion rates suggest that utilization of mid-shelf clastics as a source of sand would not interfere with the normal nearshore inner shelf sediment system. In fact, unless this sediment is used, much of it will become unavailable.

Shelf sediments off Long Beach-Huntington Beach include a broad lens of modern sediment. This sediment may have been eroded from the shoreline along Newport Beach during the past 10 years. Nearer Long Beach the modern shelf sediment forms a migrating series of giant sand ripples. These ripples may represent modern sediments that are feeding beaches.

Investigation of canyon

In the Newport Beach area, heavy metal tracers from outfalls were used to determine sediment transport over the shelf and into Newport Submarine Canyon. This sediment is less than seven years old as dated from the beginning of deep outfall operations in 1969. A mid to inner shelf trend and high concentrations in the canyon indicate filling of the canyon by these fine-grained sediments. However, high current velocities in excess of 18 cm/sec, measured in collaboration with F. P. Shepard during December, 1974, indicate down-canyon transport of sand is possible. Along the canyon axis, sharp, clean seismic profiles indicate an active canyon.

A completed isopach map of unconsolidated sediments for the area seaward of the San Diego County shoreline indicates that modern sediments form a wedge thickening from the shore to the (-) 20 m contour, and from this maximum thickness of 20 m thin to 0 m near the shelf-break. Storm wave control of the steepening seaward edge of the sediment wedge between -20m and -40m depth contours is postulated. Ripple marks and the configuration of this sand wedge suggest that these deposits are currently feeding beaches. Beneath this sediment wedge buried stream channel deposits and submarine terrace scarps are present.

Techniques and research results were presented at scientific meetings, including the American Association of Petroleum Geologists, Dallas, Texas, The Geological Society of America, Miami, Florida and its Cordilleran Section Meeting in Los Angeles, California and the Offshore Technology Conference. Seminars were presented to the Shore Processes Group, Scripps Institution of Oceanography, the Bureau of Land Management - Southern California Bight "Baseline Study" meeting in Long Beach and various academic institutions.

Publications

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Lee, C., Reflection profiling and trace metal geochemistry of the Newport submarine canyon region, Newport Beach, California, M.S. thesis, 1975 (C.S.U.N.)

Cooperating Organizations

Atlantic Richfield Company, Los Angeles, California
California Division of Oil and Gas, Long Beach, California
California State Lands Division, Long Beach, California
McCutcheon, *et al.*, Attorneys, Los Angeles, California
Mobil Oil Company, Los Angeles
San Diego County, County Engineer
Shell Oil Company, Houston, Texas
Shepard, F.D., Geological Research Division, S.I.O., La Jolla, California
Signal Oil Company, Long Beach, California
Southern California Edison Company, Los Angeles, California
University of Southern California, Los Angeles, California
United States Army Corps of Engineers, Los Angeles, California
United States Geological Survey, Menlo Park, California
United States Navy,
Naval Civil Engineering Laboratory, Pt. Hueneme, California
Naval Undersea Center, San Diego, California
Pacific Missile Test Center, Pt. Mugu, California

Ecological Studies of the Nearshore Zone

Paul K. Dayton

The central objective of this program was to provide the ecological knowledge necessary for the establishment of a rational coastal management program based on maintaining integrated commercial, recreational and aesthetic values. This management depends upon the ability to predict the effects of perturbations from pollution, harvesting, recreational uses, sedimentation and other factors, and to distinguish such changes from natural fluctuations.

The central focus of this project during the past five years has been the examination of the structure and stability of a number of biological communities within the nearshore environment of southern California. Specifically, we have been monitoring communities developing on hard substrata, i.e. kelp beds, intertidal and subtidal components of the La Jolla Ecological Preserve, and artificial boxes and reefs placed off the SIO pier; and the community of sand organisms from various depths in the vicinity of La Jolla Shores. The areas selected for monitoring represent the majority of nearshore benthic communities found in southern California. Within community types we have examined a variety of habitats in several areas. The kelp bed studies, for instance, have included sites at Pt. Loma, Del Mar, and Catalina Island. This base-line knowledge is essential for differentiating the natural variation of these communities from the variation potentially resulting from man's influence on the coastal environment. These long-term studies will give us a more complete understanding of the nearshore benthic environment and a better framework for the management of this multi-use resource.

La Jolla Ecological Preserve

The intertidal zone is an environment subjected to intensive human pressure. Large areas of algal cover have disappeared and once-abundant game species such as abalone and mussels have become increasingly rare. Since the uses of this resource are numerous and often in conflict, the La Jolla Ecological Preserve was established to maintain an inter- and subtidal rocky habitat in an optimal state for the reestablishment of former population levels. We have been comparing the success of this preserve status with an unprotected intertidal zone at Bird Rock. This monitoring comprised 13 permanent 25 m^2 quadrats, seven in the Ecological Preserve and six at Bird Rock, and two subtidal 40 m transects in the Preserve. The transects in the Preserve have failed to show any significant increases in game species, and a slight decrease in numbers of abalone suggests that poaching is taking place. (The Preserve is still a popular shell collecting area.) At any rate, the fact that large numbers of legal abalone (9/40 m^2) can still be seen subtidally here is encouraging. The Preserve is too small to protect migratory game such as lobster; its boundary is clearly delineated by rows of lobster traps during the season, thereby trapping most of the lobsters that would otherwise enter the Preserve. The intent of this Preserve might be better realized with more strongly worded signs and additional enforcement of the law.

The kelp bed studies have shown a large natural variation in *Macrocystis* densities over time. The most important cause of mortality is large drifting plants which "snowball" through the kelp bed tearing up additional plants. Recruitment of new plants is sporadic, but appears to be associated with a combination of high light levels and unknown water factors during the spring. This study will continue under National Science Foundation support. In addition, the Sea Grant supported sea urchin fishery program is generating valuable base-line data on urchin populations within the kelp habitat.

Fager, in a major study of the epifaunal sand bottom community off the SIO pier, reported extensive population data and concluded that this community is surprisingly stable. However, our recent studies in this same area have shown large changes in the population levels of some of these organisms. For example, the sea pansy, *Renilla kollikeri*, which Fager recorded at a density of 1.68/m^2, had declined to a density of only 0.50/m^2 in August, 1974. In late August a large larval recruitment of *Renilla* increased the density to 35/m^2. This large year class declined steadily until a stable population level of 5/m^2 was reached in February, 1975. Two other conspicuous members of the sand community which have experienced large population increases during the past two years are the sea pen, *Stylatula elongata*, and the tube building worm *Diopatra splendissima*.

Monitoring of the benthic community on artificial structures, some of which have

been in place on the sand bottom as long as eight years, has continued. The most significant change during the 1974-75 period was the large settlement of the red alga, *Gigartina* sp. The underwater television system, which was installed last year with great hopes for continuous observation, was inoperative a good part of the time due to technical problems with the cable. A new cable was installed during September, 1975.

Two kinds of artificial plant habitats have been created on the sand bottom near the SIO pier. An artificial kelp bed was extremely successful in attracting fish and a wide variety of invertebrates, including lobsters, crabs, starfish, nudibranchs, hydroids, and bryozoans. We will incorporate what we learned from the artificial kelp into the artificial reefs that we plan to construct this fall. The artificial eelgrass bed was less successful because it quickly snared a great deal of drift algae. It did attract fish however, most notably the sand bass *Paralabrax clathratus* and *P. maculatofasciatus*. Since the tangled mass of drift algae combined with the artificial *Zostera* bore no resemblance to natural eelgrass, the experiment was abandoned.

To relate this work on the sand bottom community to our studies on artificial structures, we are looking at the effects of artificial reefs on the sand bottom fauna. In April of 1975, a large rock reef was constructed in 40 feet of water approximately a mile north of the SIO pier. The physical effects of the reef appear to be minimal, but the biological disturbance to the sand community is significant. Within two weeks of the reef's construction, sea pens near the reef had bare tops, indicating grazing by some predator associated with the reef. By June, sea pens had virtually been eliminated within 20 meters of the reef. In September, 1975, an effect could be seen 90 meters from the reef. The probable predator is the sand bass, *Paralabrax clathratus*, but this will have to be tested further.

The major aim of the research on the colonizing alga, *Sargassum kjellmanianum*, during the past year was to determine the distributional limits of the species and the potential problems which might arise within these limits. The survey of Mission Bay has been completed. The *Sargassum* population appears to have reached its maximum level with limited new hard substrata available for colonization. There is little possibility of growth of *Sargassum* in the muddy or sandy portions of the bay due to high rates of siltation which smother young plants. New populations of *Sargassum* have been found in Santa Barbara Harbor, Berkeley Marina in San Francisco Bay, and San Quintin Bay in Baja California. The population in California appears to be moving north and south from a center around San Diego.

A shipment of Japanese oyster spat to Washington State was inspected to determine if *Sargassum* or any new exotic species was being transported to the West Coast by this practice. Of the many species associated with the oyster spat there appeared to be no new potential exotics. Most of the species have already become established along the coast, and the remaining species, such as the barnacle *Amphitrite amphitrite*, are not capable of reproducing in the colder waters of the Pacific Northwest.

We have increased our communication with British researchers working on *Sargassum* populations along the southern English coast where this species first appeared in February, 1973. The British Government has organized a large eradication program which will examine various methods for eliminating this seaweed. We will follow the results of this program looking for methods which could be applied here in Mission Bay where *Sargassum* is a problem.

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Cooperating Organizations

National Marine Fisheries Service, La Jolla, California
California Department of Fish and Game, Long Beach and Sacramento, California
City of San Diego, California
San Diego County Planning Commission
Regional and State Boards of the Coastal Planning Commission
Local and Regional Water Quality Control Boards
Mission Bay Associates, San Diego, California
Kelco Company, San Diego, California

Subtidal Ecology of Carmel Bay

Moss Landing
Marine Laboratories
R/CZ-21

T. W. Thompson

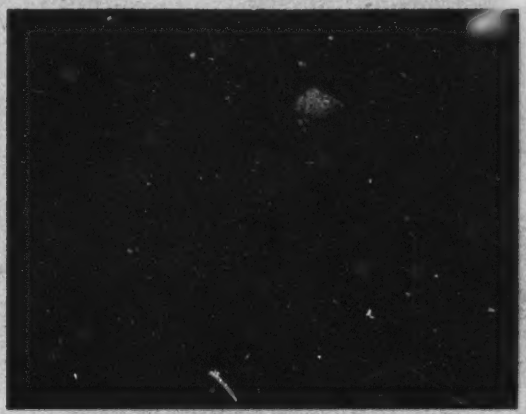
To evaluate the suitability of Carmel Bay for a future underwater park or ecological reserve, a long-term study has been undertaken by Moss Landing Marine Laboratories of the benthic communities of the bay and the impacts of kelp harvesting upon them. A course has been initiated in subtidal ecology in which each class member investigates a specific organism, habitat, or technique.

During the autumn of 1973 there was considerable discussion in central California concerning the possibility of establishing an underwater park in Carmel Bay. This bay, one of the most beautiful along the California coast, is the site of a variety of recreational and commercial activities. At its south end, the state maintains the Point Lobos Ecological Reserve. At San Jose Beach immediately to the north can be found a major center for scuba diving. At Carmel City Beach, one encounters enthusiastic participation in surfing. Still further to the north, Stillwater Cove is the base of a recreational sailing fleet. Offshore, kelp bed resources sustain the majority of the party boat fishing industry centered in Monterey. These kelp beds are harvested from time to time, particularly when the resource in southern California cannot satisfy the alginate industry.

Predictably the park proposal met with a varied response from user groups, some supporting it wholeheartedly, others viewing it with suspicion. The Sea Grant Advisory Services program at Moss Landing had taken an active interest in Carmel Bay as a result of requests for assistance from the Department of Parks and Recreation. Assistance was provided with access surveys and habitat descriptions. As community interest increased, it became apparent that the data base concerning Carmel Bay was inadequate to answer many of the questions raised. Individuals from the Departments of Parks and Recreation and Fish and Game and the Sea Grant program at Moss Landing agreed that a proposal for limited funding to initiate a long-term study program would be appropriate. This research was proposed and subsequently funded by Sea Grant.

Course in subtidal ecology

The long-term program was designed to monitor the health of benthic communities and to provide information on various groups of benthic plants and animals for use in generating interpretative materials for the proposed park. With the development, under Sea Grant auspices, of a course in subtidal ecology, the program has been initiated. Recently approved by the Moss Landing Marine Laboratories Governing Board and the Schools of Science of the consortium campuses, the course involves class members in the conduct of ecological surveys of the kelp beds. It also requires an individual project designed to provide information on a specific organism, habitat or technique of special interest. To date the class has surveyed habitats in Carmel Bay in water depths ranging from 35 ft to 120 ft, established a permanent study site for annual sampling in the "Great Kelp Bed" off Carmel Beach, and compared Carmel Bay kelp beds with those found in southern Monterey Bay. Completed class projects include: photographic documentation of Carmel Bay habitats; studies of bottom dwelling kelp bed fishes and their food habits; preliminary studies on gastropod molluscs and understory algae; vertical distribution of decapods on *Macrocystis pyrifera*; attempts to develop a method for measuring the growth rate of haptera of the giant kelp; and the development of an inexpensive integrating light meter for use underwater. In addition, two graduates of this class have elected to undertake master's research in conjunction with the Sea Grant study.



MLML graduate student Dennis Eimoto places a captured rockfish in his "goody" bag for subsequent food habit studies. Photo: Robert King

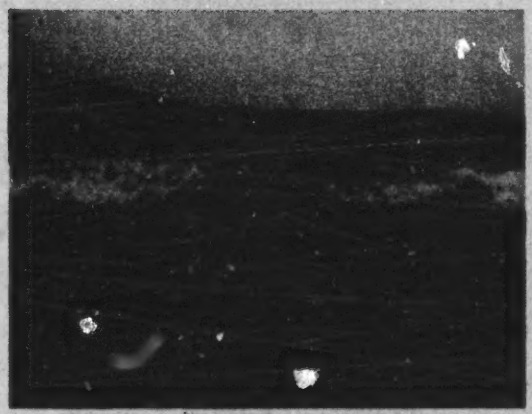
One study concerns the population structure of the understory algae in the Great Kelp Bed. It seeks to determine seasonal changes in understory algal populations as well as effects of various levels of kelp harvesting upon them. Four permanent study areas, quarter-hectare in size, have been established. Twenty five 10 m^2 quadrats in each have been mapped and the algae counted. The dominant species are *Pterygophora californica*, *Cystoseira osmundica*, *Macrocystis pyrifera*, *Desmarestia tobacoides*, *Laminaria* sp., *Weeksia reticulata*, and *Schizymenia* sp. Two areas, one control and one harvested, are sampled monthly, and the other two quarterly.

A modified line intercept technique is employed to sample species which are small and clumped in their distribution. Organisms occurring below and above randomly spaced knots on a 3 m line are recorded. One thousand knots are sampled in each study area. Again, two of the study areas are sampled monthly and two quarterly. This has generated per cent cover information on benthic animals and plants and an estimate of bottom types. The dominant clumped plants are *Plocamium coccineum*, articulated coralline algae belonging to the genus *Calliarthron*, and encrusting coralline algae of the genus *Lithothamnion*.

A second student has been studying the snails which occur on the *Macrocystis* plants in the same four study areas in the Great Kelp Bed. This study was suggested because these gastropod molluscs apparently form a direct link between the kelp, upon which they feed, and the sea ottor, which consumes them.

Eighty *Macrocystis* plants have been tagged and are being observed at varying intervals throughout the year. To date, over 4500 snails have been counted. Dominant species include *Tegula pulligo*, *Tegula montereyi*, *Calliostoma ligatum*, *Tegula brunnea*, *Calliostoma annulatum*, and *Calliostoma canniliculatum*. Statistical analyses indicate no significant difference between spring and summer distributions of the two most dominant species (*T. pulligo* and *T. montereyi*). However, the numbers of snails found in these periods were considerably different, many more being recorded during summer than spring. Analyses of vertical distribution indicate that *T. pulligo* and *T. montereyi* are mutually exclusive, perhaps a result of the fact that they compete for the same food and space.

Studies of the effects of kelp harvesting on snail distribution involved counts before and after one study area was cut in June. These



Student investigator on the Carmel Bay subtidal ecology project maneuvers through the surf on return from the "Great Kelp Bed." Photo: Robert King

data indicate a greater concentration of snails at the base of the plants after harvest than before. Apparently the animals were dislodged by agitation from the harvester blades. Distributions of *T. pulligo* and *T. montereyi* were significantly different between the immediate post-harvest period and one month later, although the total number of animals in the harvest area did not seem to be meaningfully affected.

Capture and release experiments involved marking 75 snails with epoxy paint and placing them on or at the base of the plant from which they were collected. The marked snails were generally found to reoccupy the plant from which they had been removed, although *T. pulligo* demonstrated more inclination to move to other plants than *T. montereyi*.

The studies of both graduate students and many of the class projects are being coordinated with research being conducted by the Monterey laboratory of the Department of Fish and Game. Department investigators working in the same four study areas are endeavoring to determine effects of kelp harvesting on the *Macrocystis* plants themselves as well as on commercially and recreationally important species of fishes believed to use the kelp forest as a nursery ground. These investigators have requested assistance from the Moss Landing Sea Grant program in extending their studies to include understory algae, invertebrates and other fish species.

Cooperating Organizations

California Department of Fish and Game, Monterey, California

California Department of Parks and Recreation, Monterey, California

Del Monte Properties Beach and Tennis Club, Pebble Beach, California

Management of Beach and Dune Vegetation

Davis
R/CZ-22

Michael G. Barbour

Repeated samplings of transects have revealed the natural extent of winter erosion and plant reinvasion along a portion of Point Reyes National Seashore. The accuracy of measurements was enhanced by construction of a "dune profiler" instrument and a frame permitting vertical photos of the transect. The data were extrapolated to the design of future artificial plantings for erosion control.

Our first year's work had as its objective the determination as to which native species are most promising for artificial plantings in the control of beach and dune erosion. We wish to find a substitute for European beach grass (*Ammophila*), which has been widely planted for erosion control but has the negative traits of crowding out native species and grossly altering natural landforms. Our approach was threefold: observing the natural extent of erosion and plant reinvasion in non-manipulated vegetation; observing plant survival in small-scale transplant "gardens" in the field; and conducting germination and asexual reproduction trials of several species in the greenhouse.

Permanently marked transects

The National Park Service at Point Reyes National Seashore has been very cooperative with our establishment of permanently marked transects through beach and fore-dune vegetation. The transects were sampled for topographic and vegetative features in November, 1974 and June, 1975. A simple, but accurate, method of measuring beach topography has been developed, and the transects were also photographed from above; the photos are clear enough to serve as a very precise record of plant cover. Winter storms resulted in the removal of a top layer of sand as much as 2 m thick (in a period of about six months) on portions of the transects, with considerable changes in plant cover and reinvasion. Additional transects and sample periods are scheduled for 1975-76.

From the first-year observations, one can extrapolate to the design of future experimental plantings. American dune grass (*Elymus*) has a rapid colonizing ability and can be used as a matrix in which two other natives, sand verbena (*Abronia*) and beach bur (*Ambrosia*) can be located. The short-lived pioneers' salt bush (*Atriplex*) and sea rocket (*Cakile*) are not suitable for dune planting and should be weeded out to prevent competition with the above dune formers.

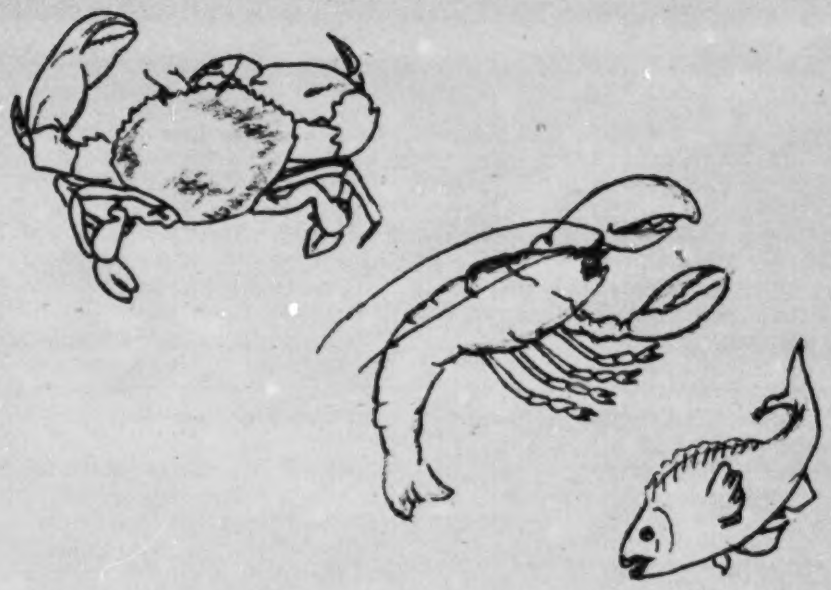
Transplant experiments with *Ammophila* and *Elymus* were begun in February, 1975. Vegetative material was collected from the surrounding area and planted in different densities, with different amounts of slow-release fertilizer, and in pure or mixed species arrangements. Survival and growth were noted five months later. When grown alone or in mixture, *Ammophila* had a greater survival rate than *Elymus*. However, the survival rate of *Elymus* appears to have been enhanced when grown with *Ammophila* rather than alone. Planting density and fertilizer level did not affect survival, but after this initial establishment period we anticipate that density and nutrient level will assume greater importance. Two planting periods had similar temperatures but differed considerably in the amount of rain falling in the two weeks just after planting. Survival was considerably greater for the planting followed by heavier rainfall.

Accurate plant biomass estimation

Monitoring of these transplant gardens will continue in 1975-76 and additional gardens will be established based on the lessons and techniques learned. Test samples show that a non-destructive method of accurately estimating plant biomass is feasible by measuring plant height or length, and width of the largest leaf. Consequently, we shall be measuring growth as well as survival next year.

Finally, greenhouse experiments have shown that *Abronia* may be propagated readily from seed if the fruit wall is removed before sowing. *Ambrosia* also germinates well if the fruit is first leached with running water and nicked with a blade. Several other species have also been germinated successfully. Stem cuttings of *Ambrosia* quickly root in sand if a dilute concentration (less than 1 per cent) of the synthetic plant hormone IBA is applied. Next year we shall attempt field transplant trials of *Abronia* and *Ambrosia* from seed and cuttings in a mixture with *Elymus*.

Cooperating Organizations
United States Park Service, through Point Reyes National Seashore



AQUACULTURE

The importance of the commercial culture of marine animals and plants for human use has long been recognized. In some instances this kind of husbandry has been successfully developed. Natural stocks of preferred species such as the American lobster are subject to increasing exploitation pressures and even with optimal management will probably be insufficient to meet future market demands. Thus there is considerable interest in increasing the available supply by commercial rearing. Several Sea Grant projects address various aspects of this problem. Knowledge gained in the husbandry of valuable species could ultimately lead to practical mass culture of other species to help meet increasing world demands for protein foods. In recognition that derivatives of seaweeds are becoming increasingly valuable and important, other research scientists are directing their efforts toward an understanding of marine plant resources so that they may be properly utilized in ways that are not environmentally damaging. An unusual research activity explores breeding crop plants to tolerate irrigation with highly saline water.

Development of Aquaculture Systems

Robert A. Shleser

The Aquaculture Program at the Bodega Marine Laboratory is a coherent, interdisciplinary effort which continues to investigate the feasibility of the commercial cultivation of the lobster, *Homarus americanus*. Significant accomplishments have been made in several areas.

Water quality

Project Leader: R. Daggett

Further progress has been made in developing automated systems which monitor the water quality for aquaculture projects, and over the past year a continuous weekly monitoring program has been maintained designed primarily to assist other interdisciplinary programs with their research. Techniques have been refined for automated and manual seawater analysis, particularly for ammonia, nitrite, nitrate, phosphate, total carbon, and total nitrogen by the Kjeldahl method. Over 20 months of continuous water quality data on ambient seawater and various culture systems, comprising about 16,000 assays, have been accumulated.

Genetics

Project Leader: D. Hedgecock

We constructed a facility for the study of reproduction in *Homarus americanus* and are currently importing mated, but unberried, females to see whether conditions can be provided for egg extrusion and successful hatching. A study was made of growth in juvenile lobsters and it was found that up to 30 per cent of the considerable variation in growth rates may be due to heritable differences. It was also shown that the growth rate is extremely sensitive to water quality and the genotype and environment may interact to make growth rate prediction hazardous.

We described the Mendelian inheritance of 10 allozymes in both the European and American species of *Homarus* and presented a review, "Applications of Biochemical Genetics to Aquaculture", at the XIII Pacific Science Congress, Vancouver, 1975. The two species of *Homarus* have been mated in both directions, and we obtained genetic evidence that female lobsters may be inseminated by more than one male.

Nutrition

Project Leader: D.E. Conklin

Last year's work on the development of suitable diets was continued and resulted in the formulation of semi-defined artificial diets for *Homarus americanus*. The influence of specific diet ingredients, such as vitamins, minerals, chitin, on the growth of lobsters was investigated. We further evaluated food consumption of the lobster with respect to live brine shrimp, artificial diets, and different feeding frequencies and lighting conditions. The optimum protein requirement of the spot prawn was determined utilizing a basic lobster diet.

Algology

Project Leader: M.C. Hartman

Our aim in this area was to investigate the use of marine primary producers and primary consumers in the food chain to improve the economics of aquaculture. Our approach in this was twofold: 1. To remove nitrogenous wastes from aquaculture effluent with marine phytoplankton; and 2. to rear bivalve filterfeeders on waste-grown phytoplankton.

We evaluated several species of marine phytoplankton as to ammonia nitrogen removal capabilities at those levels near and below toxicity to lobsters; established a low-maintenance compact recirculating shellfish rearing system, and evaluated under laboratory conditions an experimental biological filter system proposed by R. Srna, University of Delaware Mariculture Program.

We also demonstrated the closed system rearing of several commercially valuable shellfish species, and began the design of a flow-through algal culture system which emphasizes low contaminatability, high efficiency, and flexibility to changing nutrient conditions. A working relationship was established with a commercial shellfish industry to cooperate in future experimental areas such as the effects of various microorganisms on shellfish larvae and juveniles.

Microbiology and pathology

Project Leaders: E. H. Nilson and W. S. Fisher

As mentioned in last year's report, in larval systems it has often been found necessary essentially to sterilize the recirculating water and to disinfect the lobster—procedures which are accomplished by treating the water with ultraviolet light and the animals with malachite green. We have now defined the toxicity levels of malachite green on lobster

larvae. We also showed that the susceptibility to chitinolytic bacteria is effected by diet and chemical treatment in juveniles; isolated a variety of potentially pathogenic chitinolytic bacteria for further study, and designed and developed a larval bioassay system.

We worked in conjunction with the Nutrition Program by routinely examining mortalities and ascertaining whether the cause was disease or diet related, and observed gross symptoms of chemical and physical stresses such as those from ammonia, temperature and copper.

Systems engineering and economics
Project Leader: L. W. Botsford

Continuing the work of calculating the costs of various models for aquaculture, we have determined optimal values of control variables for three realistic culture systems and presented the results at World Mariculture Society Meetings, 1975. We also completed the analysis of data from a temperature experiment, the manuscript of which is in press, and began the preparation of a document describing modeling optimization and simulation of the economics of aquaculture in collaboration with A.M. Schuur and P.G. Allen.

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Cooperating Organizations

Agromarina de Panama, S.A., Panama
Boisa Aqua, Huntington Beach, California
California Department of Fish and Game, Monterey, California
East Carolina University
Fisheries Research Board of Canada, St. Andrews, New Brunswick, Canada
Fishermen's Association, Bodega Bay, California
Foremost Foods Research Lab, Dublin, California
International Shellfish Enterprises, Inc., Moss Landing, California
Ralston Purina, Crystal River, St. Louis, Missouri
San Diego State University, California
San Francisco Bay Brand Shrimp, California
Sanders Associates, New Hampshire
State of California, Regional Water Quality Control Board
University of Delaware
University of Hawaii
University of Rhode Island, Department of Zoology
P. Wilson, Monterey, California

Economics of Aquaculture

Warren E. Johnston

Considerable modification and refinement have been accomplished in a computerized budget model for assessment of production costs for lobster aquaculture, the object of which is to determine the minimal-cost manner of lobster production in a controlled environment.

Lobster/budget is a systems-like computer model incorporating biological, engineering, and economic relationships used to estimate costs and physical requirements for hypothetical lobster culture systems. A detailed series of state and control variables, parameters, and identities are used. The objective is to determine the least-cost manner of lobster production in a controlled environment. Biological relationships identified include growth, survival (mortality), feed consumption, metabolite production, minimum water flow rate, and oxygen consumption functions. Performance measures include the cost per unit output for each major component in the production system (e.g., space, heat, pumping, waste treatment, food, etc.), harvest weight, time to harvest, monthly output, required capital costs, water intake flow, tank area, and feed conversion ratio. *Lobster/budget* is more than a computerized accounting routine in that it has usefulness in assessing sensitivity of performance measures to alternative levels of state variables or parameter estimates. Thus, it assists research managers in evaluating the current state-of-the-art with possible research outcomes in a cost-effective framework.

Tables 1-3 summarize current output from *Lobster/budget*, based on selected state variables and parameter estimates. Table 1 summarizes cost and other performance measures in a Base-line Model for an hypothetical production facility with an operating temperature of 21°C, a plant size of 80,000 harvestable animals per month, zero recirculation of water flow, and space and genetic stock capable of reaching 500 gram target harvest weights in 30 months. Estimated total cost of production is $5.65 per lobster, of which the cost of heating accounts for $3.19, suggesting that lower cost heat alternatives justify further investigation. Other major cost components are for food ($1.02), for space ($0.75), and for non-feeding labor and supervision ($0.41).

TABLE 1

Base-line Model Outcomes, Lobster Budget Model with 500 gram/animal Target Weight (Winter 1975)

Cost Summary ($ per unit output):	
Space	$0.75
Heat	3.19
Pumping	0.07
Waste treatment	0.09
Aeration	0.05
Food	1.02
Feeding labor and equipment	0.03
Other labor	0.41
Larvae	0.04
TOTAL COST	$5.65
Other information (from printout summary):	
Months to output	30.0
Plant output (thousands/month)	80.0
Harvest weight (grams/animal)	502.6
Total capital ($100,000)	31.05
Culture capital	(25.22)
Waste treatment capital	(5.83)
Tank area (1000 m^2)	98.95
Water reuse (% recirculation)	0.00
Intake flow (million liters/day	43.45
Land area for production facility (hectares)[a]	2.75
Conversion ratio	3.30

[a] Does not include land area for waste treatment facility.

Results

The cost results from *Lobster/budget* are most useful in examining consequences of changes in variables or parameters. Tables 2 and 3 show sensitivity to values differing from those contained in the Base-line Model. For example, a 19°C operating temperature regime in the hypothetical production facility produces harvestable animals costing $4.88 each (rather than $5.65 for the 21°C regime of the Base-line Model). Heat savings most importantly contribute to the lower cost, while space and labor costs increase. Other examples are depicted.

Publications

Schuur, A.M., P.G. Allen, and L.W. Botsford, An analysis of three facilities for the commercial production of *Homarus americanus*. Paper presented to the American Society of Agricultural Engineers, Chicago, Illinois, December 1974.

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Cooperating Organizations

Collaborative Sea Grant Projects R/FA-4 and R/FA-17

TABLE 2

Sensitivity of Base-line Model Outcomes to Alternative State Variable or Parameter Values—Operating and Average Ambient Temperatures, Recirculation Coefficient, and pH

System Cost and Physical Characteristics	Alternative State Variable or Parameter Values (less than Base-line Model)				Base-line Model	Alternative State Variable or Parameter Values (greater than Base-line Model)				
I. OPERATING TEMPERATURE:	13°C	15°C	17°C	19°C	21°C					
Total Cost	**$4.47**	**$4.22**	**$4.34**	**$4.88**	**$5.85**					
Space	1.75	1.30	1.04	0.88	0.79					
Heat	0.40	0.87	1.45	2.23	3.19					
Pumping	0.04	0.05	0.05	0.06	0.07					
Waste treatment	0.10	0.10	0.09	0.09	0.09					
Aeration	0.05	0.05	0.05	0.05	0.05					
Food	1.12	1.08	1.04	1.03	1.02					
Feeding	0.08	0.04	0.04	0.03	0.03					
Other labor	0.90	0.88	0.55	0.47	0.41					
Juveniles	0.04	0.04	0.04	0.04	0.04					
Months to output	70.67	52.67	42.0	35.0	30.0					
Total capital ($100,000)	51.0	46.9	38.7	34.2	31.1					
Tank area (1000 m^2)	229.8	171.0	135.7	114.9	99.0					
Intake flow (million l/day)	25.0	28.6	32.4	37.7	43.5					
II. PLANT SIZE (monthly output):	10,000	20,000	40,000	60,000	80,000	100,000	150,000	200,000	250,000	
Total Cost	**$7.02**	**$6.18**	**$5.81**	**$5.70**	**$5.66**	**$5.61**	**$5.57**	**$5.55**	**$5.54**	
Heat	3.42	3.31	3.24	3.21	3.19	3.18	3.16	3.15	3.14	
Pumping	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	
Waste treatment	1.22	0.50	0.21	0.13	0.09	0.07	0.05	0.05	0.05	
Total capital ($100,000)	5.0	9.0	16.5	23.9	31.1	38.2	55.7	73.0	90.1	
Tank area (1000 m^2)	12.4	24.7	49.5	74.2	99.0	123.7	185.5	247.4	309.2	
Intake flow (million l/day)	5.4	10.9	21.7	32.6	43.5	54.3	81.5	108.6	135.8	
III. RECIRCULATION COEFFICIENT (R):					0	0.1	0.3	0.5	0.7	0.9
Total Cost					**$5.66**	**$5.59**	**$5.16**	**$4.72**	**$4.26**	**$3.78**
Heat					3.19	2.97	2.51	2.03	1.53	1.01
Pumping					0.07	0.07	0.06	0.05	0.04	0.02
Waste treatment					0.09	0.25	0.29	0.34	0.39	0.44
Total capital ($100,000)					31.1	35.2	39.0	41.7	43.8	45.6
Intake flow (million l/day)					43.5	39.5	31.4	22.9	14.0	4.8
IV. SPACE (tank area/unit output):			4.58 m^2	1.92 m^2	1.24 m^2	0.96 m^2	0.80 m^2	0.70 m^2		
Total Cost			**$7.84**	**$5.96**	**$5.66**	**$5.67**	**$5.80**	**$5.95**		
Space			2.80	1.17	0.75	0.58	0.49	0.43		
Heat			2.93	3.06	3.19	3.35	3.52	3.67		
Pumping			0.07	0.07	0.07	0.07	0.08	0.08		
Aeration			0.04	0.04	0.05	0.05	0.05	0.06		
Food			0.93	0.98	1.02	1.08	1.14	1.20		
Feeding			0.10	0.04	0.03	0.02	0.02	0.01		
Other labor			0.85	0.49	0.41	0.38	0.37	0.37		
Months to output			26.0	28.0	30.0	32.0	34.0	36.0		
Total capital ($100,000)			99.0	44.7	31.1	25.4	22.5	20.7		
Tank area (1000 m^2)			386.7	153.2	99.0	78.4	64.0	56.1		
Intake flow (million l/day)			39.9	41.7	43.5	45.7	48.1	50.2		
V. TARGET WEIGHT (monthly output):	100 g (296,000)	200 g (186,400)	300 g (122,400)	400 g (94,000)	500 g (80,000)	600 g (68,000)				
Total Cost	**$1.98**	**$2.33**	**$3.34**	**$4.82**	**$5.88**	**$6.86**				
Space	0.21	0.36	0.49	0.64	0.75	0.89				
Heat	0.54	1.19	1.79	2.58	3.19	3.95				
Pumping	0.01	0.03	0.04	0.06	0.07	0.09				
Waste treatment	0.03	0.06	0.06	0.08	0.09	0.10				
Aeration	0.01	0.02	0.02	0.04	0.05	0.06				
Food	0.17	0.37	0.56	0.82	1.02	1.26				
Feeding	0.01	0.01	0.02	0.02	0.03	0.03				
Other labor	0.20	0.27	0.31	0.37	0.41	0.45				
Months to output	17.33	22.0	25.33	28.0	30.0	32.0				
Total capital ($100,000)	29.6	30.2	30.5	30.9	31.1	31.2				
Intake flow (million l/day)	27.0	33.6	37.1	41.0	43.5	45.8				
Cost/500 grams	5.71	5.84	5.42	5.59	5.62	5.65				

TABLE 3
Sensitivity of Base-line Model Outcomes to Alternative State Variable or Parameter Values—Plant Size, Space, Target Weight, and Time to Maturity

System Cost and Physical Characteristics	Alternative State Variable or Parameter Values (less than Base-line Model)			Base-line Model	Alternative State Variable or Parameter Values (greater than Base-line Model)			
VI. AVERAGE AMBIENT TEMPERATURE:			10°C	12°C	14°C	16°C	18°C	20°C
Total Cost			**$6.27**	**$5.65**	**$5.02**	**$4.38**	**$3.75**	**$3.13**
Heat			3.82	3.19	2.56	1.93	1.30	0.67
Total capital ($100,000)			31.5	31.1	30.5	29.9	29.2	28.4
VII. pH	7.5	7.7	7.9	8.0	8.1	8.3	8.5	
Total Cost	**$3.59**	**$4.59**	**$5.01**	**$5.65**	**$6.44**	**$8.83**	**$11.83**	
Heat	1.05	1.84	2.56	3.19	3.97	6.13	9.35	
Pumping	0.02	0.04	0.06	0.07	0.09	0.13	0.21	
Waste treatment	0.12	0.10	0.09	0.09	0.09	0.06	0.06	
Aeration	0.06	0.05	0.05	0.05	0.04	0.04	0.03	
Total capital ($100,000)	28.5	29.4	30.4	31.1	31.8	33.4	35.5	
Intake flow (million l/day)	14.0	22.1	34.7	43.5	54.3	84.3	129.3	
VIII. TIME TO MATURITY (months):		24.0	27.0	30.0	33.3	36.0		
Total Cost		**$4.91**	**$5.29**	**$5.65**	**$6.06**	**$6.46**		
Space		0.62	0.67	0.75	0.82	0.90		
Heat		2.81	3.02	3.19	3.40	3.61		
Pumping		0.06	0.07	0.07	[illegible]	0.08		
Waste treatment		0.09	0.09	0.09	0.09	0.09		
Aeration		0.04	0.04	0.05	0.05	0.06		
Food		0.89	0.96	1.02	1.10	1.18		
Feeding		0.02	0.02	0.03	0.03	0.03		
Other labor		0.34	0.37	0.41	0.44	0.48		
Months to output		24.0	27.0	30.0	33.0	36.0		
Total capital ($100,000)		28.2	29.1	31.1	33.5	36.5		
Tank area (1000 m^2)		81.8	88.0	99.0	107.6	118.5		
Intake flow (million l/day)		38.2	41.1	43.5	46.4	49.3		

Protective Measures for Lobster Culture

San Diego
R/FA-7

Harriette C. Schapiro and James F. Steenbergen

Immunization of the American lobster to gaffkemia has been investigated. Serological studies have demonstrated the existence of a virulence antigen which may be masked in some strains of the pathogen, *Aerococcus viridans*; and techniques have been developed for studying *in vitro* phagocytosis by lobster hemocytes. *Leucothrix* and other infections are also under study.

Immunological studies for the protection of the American lobster against gaffkemia were continued. Previous studies had shown protection following injection of live avirulent *Aerococcus viridans*. Selection of the best strains for use as immunogens was made on the basis of a numerical taxonomy study, which showed the identity of the lobster pathogen (formerly *Gaffkya homari* and *Pediococcus homari*) with *Aerococcus viridans*. However, it has proven difficult to establish optimal conditions for immunization; both virulence and immunogenicity vary with strain and culture conditions. The conditions under which protection is induced have been defined by Kellogg and co-workers. The problem of variable immunogenicity may be resolved by our serological studies.

We have demonstrated that a "virulence antigen" is present in all pathogenic strains of *A. viridans*. In addition, several other antigens are found in both virulent and avirulent strains. The complete antigenic schema for these bacteria is complicated by the fact that masking of some of the antigens occurs in certain strains. In order to explain the variations in virulence, immunogenicity, and masking which we have observed, we have initiated a study of the chemical nature of the cell wall antigens of these bacteria. We anticipate the use of purified cell wall antigens in future immunization experiments.

The immune response of invertebrates is primarily cellular. Phagocytosis is therefore of major importance in the disease resistance of these organisms. We have developed an *in vitro* system for the study of phagocytosis by lobster hemocytes. Avirulent strains of *A. viridans* are phagocytized by more than 90 per cent of the hemocytes in our system. In contrast, the gaffkemia-producing strains of *A. viridans* poorly phagocytized (i.e., less than 40 per cent). In addition, fewer virulent bacteria are taken up by each hemocyte. Studies comparing the phagocytic index of hemocytes from immunized and unimmunized lobsters are currently in progress. We hypothesize that immunization will increase the number of hemocytes capable of phagocytizing the virulent bacteria, and anticipate to use this *in vitro* "tissue culture" system in perfecting our immunization procedures.

Leucothrix Infections

During the past year, aquaculturists studying lobsters and shrimp have encountered high mortalities in larval and juvenile stages. These epidemics have been correlated with a high incidence of the filamentous bacterium *Leucothrix* sp., on the gills of the infected animals. The pathology of this disease has proven hard to study because of difficulty in isolating the bacteria. This apparently stems from the fact that these bacteria are more fastidious than the previously described epiphytic strains isolatable from marine algae. We have developed a new medium for the isolation of the strains found on lobsters. In the course of these isolation studies, a promising treatment for *Leucothrix* infestations, which entails the use of vancomycin, has been developed. We are also testing other chemicals for treatment of infested animals. In order to study the ecology of these infestations *in situ* on the lobster gills, we are developing a fluorescent antibody reagent for the specific detection of *Leucothrix*. Now that lobster-derived strains of *Leucothrix* are available, an attempt is being made to test Koch's postulates to determine whether this is an infective agent or a secondary invader of already diseased or stressed animals.

Other Infections

A number of gram-negative bacteria have been isolated from moribund lobsters which were infected when received from our wholesale dealer. Whether these are primary or secondary invaders will be tested. Taxonomic studies on these isolates will also be pursued in order to determine if there are systematic differences in these infections.

Several strains of chitin-digesting bacteria have been isolated from ulcerous lesions on crabs and lobsters. These bacteria not only

lower the marketability of the animals by causing unsightly lesions, but also these lesions may serve as a portal of entry for such diseases as gaffkemia. The etiology of exoskeleton lesions is complex, and probably involves several organisms.

Recently, we have autopsied several juvenile lobsters with melanized gill lobes. Similar observations have been made on shrimp. The etiology is unknown, and is under investigation.

Laginidium and other fungi have been reported to cause epidemics in lobsters and shrimp. We routinely check for their presence, but have not found them in autopsied animals.

Consulting activities

Autopsies have been routinely performed on animals received from other groups. We have worked with crabs from Harrison's group at the University of California, San Diego; shrimp from the Environmental Research Laboratory in Tucson, Arizona; and trout and lobsters from the Ford/Van Olst group at San Diego State University.

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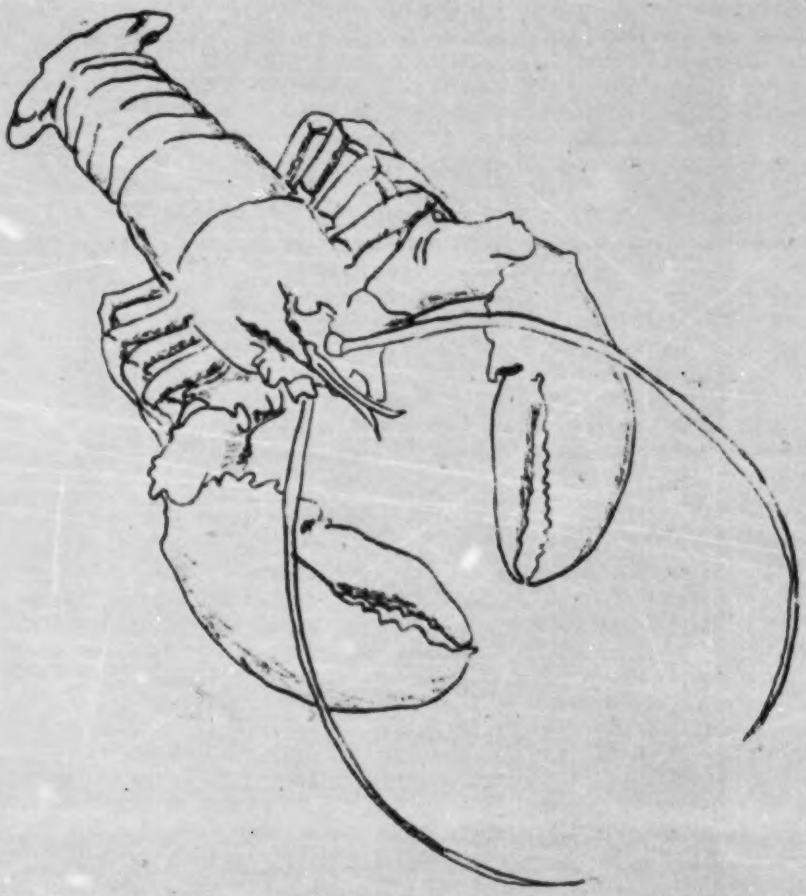
Cooperating Organizations

Environmental Research Laboratory, Tucson, Arizona
San Diego State University, California
University of California, San Diego



Use of Thermal Effluent in Aquaculture

Richard F. Ford and Jon C. Van Olst

Thermal effluent has been shown to be a valuable and economical source of clean, heated seawater for lobster culture. Growth rates of larvae and juveniles are significantly greater in mixed effluent at temperatures up to 23°C than at ambient Pacific Ocean temperatures. Survival of larvae and juveniles is essentially the same in water of effluent and ocean quality. Atomic absorption analyses of intake and effluent water samples from the Encina Power Plant and two other fossil fuel generating stations in southern California indicate that operation of these stations apparently has little effect on concentrations of Cu, Zn, Cd, Co, Cr, Pb, and As in the thermal effluent. Lobsters three years old cultured from the egg have grown to one pound and had excellent quality and flavor in a recent taste evaluation. Several types of grow-out production systems have been constructed and are being evaluated.

This research program has two major goals: to evaluate the usefulness of waste heat from electric generating stations as an inexpensive and suitable source of warmed seawater for use in aquaculture of American lobsters, *Homarus americanus*; and to develop the techniques and systems necessary for the commercially viable culture of this gourmet species. Excellent progress has been made during this past year toward both of these goals.

Research on the use of thermal effluent is being conducted at San Diego State University's Encina Thermal Studies Laboratory at the Encina Power Plant of the San Diego Gas & Electric Company in Carlsbad, California, and also at the Redondo Generating Station of Southern California Edison in Redondo Beach, California. Lobsters are being grown directly in the thermal effluent flowing from both of the fossil fuel generating stations. Concurrently sibling lobsters are being cultured at San Diego State University's Aquaculture Laboratory at the Scripps Institution of Oceanography in La Jolla, California.

Possible toxicity of chemicals present

One major aspect of the research is to assess the biological effects of chemicals associated with thermal effluent. Chlorine and heavy metal ions, such as copper, zinc, and cadmium, from the condenser systems of some generating stations could be present in concentrations high enough to have adverse effects on animals in culture, or become concentrated in their tissues to the extent that they might not be suitable for human consumption. Foods used in aquaculture, such as brine shrimp, and the plastic materials of which the culturing systems are constructed are also potential sources of toxic chemicals.

Concentration of metals in water and in lobster tissues

The results of our regular analysis, using atomic absorption methods, of intake and effluent water samples from the Encina Power Plant and two other fossil fuel generating stations in southern California indicate that operation of these stations apparently has little effect on concentrations of Cu, Zn, Cd, Co, Cr, Pb, and As in the thermal effluent. Concentrations of these metals measured in the intake and effluent water at the Encina Power Plant were not significantly different from their concentrations in seawater at the Scripps Institution, and were well within the reported ranges for levels of those metals in normal seawater. Similarly, there was no increase in these levels during heat treatment operations at the Encina Power Plant.

We observed no significant differences in concentrations of Cu, Zn, Cd, Pb, Cr, and Co in the whole-body tissues of larval, juvenile, and adult lobsters maintained in the three water types (Encina effluent, Encina intake, and Scripps). Similarities between the levels of trace metals in these whole-body tissue samples of lobsters grown in the three water types further substantiate the conclusion that chemical additions to the cooling water within the power plant probably are minimal. The levels of all six metals observed in both the whole-body samples and the edible tissues are well below the maximum allowable limits specified by the United States Public Health Service for these metals in foodstuffs.

H. americanus larvae which had been fed brine shrimp (*Artemia salina*) containing

elevated Zn levels rapidly assimilated 90 per cent more Zn into the tissues than did similar larvae which had been fed brine shrimp containing low Zn levels. This and other evidence suggests that concentrations of heavy metals in the diet appear to be more important than seawater metal concentrations in affecting the levels of heavy metals accumulated in lobster tissues.

Growth and survival of larval and juvenile lobster maintained in a series of static bioassay experiments at constant temperatures of 18 and 22°C were not significantly different in the effluent water at Encina and in the Encina intake and Scripps water sources. We have no evidence to suggest that any deaths or sublethal harmful effects were caused by toxic concentrations of metals in the thermal effluent at Encina.

More detailed descriptions of these studies are provided in two recent papers. All of the studies indicate that the thermal effluent from typical generating stations in southern California provides a clean, heated water source for the culture of *Homarus americanus*. While the results are encouraging, we are continuing to evaluate related aspects of the water quality problem.

Nutrition experiments

Our nutrition studies involve comparative evaluation of experimental shrimp rations for potential use as artificial pelletized feeds in lobster culture. We have found these diets to be deficient in promoting growth. However, when supplemented with meal from the pelagic red crab (*Pleuroncodes planipes*), some of them produce growth similar to that achieved with the nutritionally adequate brine shrimp control diet. Studies now in progress are designed to determine the degree of supplementation necessary to meet the nutritional requirements of lobsters at the lowest possible cost. This work has involved considerable cooperation with a related Sea Grant research program on lobster nutrition directed by Douglas Conklin at the Bodega Marine Laboratory.

Our research on rearing groups of lobsters together in tanks, pools, and trays (communal or mass rearing) has been under way for several years. Much of our progress made toward improving the yields from communal rearing systems for juvenile lobsters was reported in the proceedings of the 1975 meeting of the World Mariculture Society. These studies were concerned with developing methods to reduce the incidence of agonistic interactions which result in cannibalism among juvenile lobsters when reared communally. Information on substrate type, stocking density, and feeding levels indicates that communal rearing might be employed economically as an intermediate phase in a commercial culture enterprise. We are now developing techniques to increase carrying capacity of communal rearing systems and ease harvesting and waste removal for commercial-scale mass rearing systems employing thermal effluent.

The space requirements for lobsters under intensive culture conditions represent an important economic consideration in growing the juveniles and adults to market size. Because of the high rate of cannibalism in communal rearing systems, at some point in the culturing process it becomes economically prohibitive to tolerate further losses from this cause. Thus, at this point juveniles must be transferred to individual containers. We are now conducting an experiment at the Redondo Beach Biological Laboratory to determine the minimum space required for rapid growth of lobster of different life stages in individual compartments.

Another major aspect of our research program is to develop and evaluate the specific techniques and systems required for each group of life history stages in the commercial production of the American lobster. We have grown large numbers of lobsters from the egg to market size in approximately three years, using seawater of ambient San Diego temperatures averaging 16-17°C. Using thermal effluent to supply water at 22°C, it may be possible to produce animals of this size in a shorter time of approximately two years. The information gained from our studies in several areas, including larval culture, communal or mass rearing, related effects of cannibalism, growth in thermal effluent, and effects of confinement stress, has led to the design of a commercial lobster farm and its production plan.

Fig. 1. Artist's conception of potential rearing system for commercial culture of the American lobster

We have recently made considerable progress in the development of culture systems for the final phase of lobster culture, in which the animals are grown to market size. Several prototype systems that show excellent potential have been devised and are undergoing further evaluation. One, the care-O-cell, was described in our previous Sea Grant annual report. Another system may have even more potential, especially in areas where land costs are high. This flushing tray system consists of a fiberglass tray which is flushed periodically to remove wastes from lobster holding cells constructed of abs or pvc plastic. A commercial-scale version of this system would consist of groups of trays supported by 30 ft high steel cantilever racks in "lobster warehouses." A prototype model of this unit measuring approximately 2 ft 6 in x 8 ft 4 in and with rearing compartments to hold 72 lobsters separately has been constructed, and dye studies of its flow characteristics have been completed. Seawater, led in continuously through a trough along one long wall of the tray, flows through the perforated walls of each rearing container and exits through an overflow trough along the other long wall. The short partitions oriented 90° to the long perforated partitions are made of solid, unperforated plastic. The bottoms of the containers are covered with perforated screen and elevated slightly off the bottom of the tray. Once per day, or more frequently if necessary, large valves are opened at one end of the flushing tray. Because the short solid partitions act as dams to the overflow of seawater in the tray, all the water flow is forced to pass downward through the perforated bottom of each rearing container and then move rapidly across the bottom of the tray. This rapid flow has a cleaning and scouring effect on the bottom screening and on the bottom of the tray, so that the entire system is almost completely self-cleaning. The flushing tray design appears to be superior to the care-O-cell and other systems in its ability to hold large numbers of animals in a minimal amount of space, deliver oxygenated seawater evenly to each compartment, and remove wastes rapidly and economically.

Fig. 3. American lobster larvae being cultured in thermal effluent seawater in a 38 l larval culture container. The central circulator agitates the water and thereby reduces the level of cannibalism among the larvae

In the warehouse system, automated feeding units could pass through the aisles with food delivery spigots suspended over each rearing compartment at all levels simultaneously on both sides of the aisle between tray racks. Eventually an entire warehouse could be fed automatically by one or more feeders controlled by a small computer system, just as automated warehouse part-retrieval machines can now find an item stored on any level of multi-acre warehouses and deliver it to the loading dock.

Fig. 2. American lobsters cultured to a marketable size of approximately 1 lb at ambient seawater temperatures at the SDSU Aquaculture Laboratory at Scripps

Brood stock management

There has been little research on the very critical problem of brood stock management, the successful maintenance of egg-producing female lobsters. Although those conducting research on lobster culture have been able to obtain limited numbers of egg-bearing females for their work, no commercial operation could legally obtain sufficient numbers of them from wild stocks in the Atlantic Ocean to operate a commercial lobster farm on a year-round and profitable basis. Although our research group and others have succeeded in reducing the egg development time as much as four to five months by holding egg-bearing females in warm water, there is insufficient information about the processes involved to either

predict or control egg production on a large scale. We are conducting research on several aspects of this problem in cooperation with David Aiken of the Canadian Fisheries and Marine Service, St. Andrews, New Brunswick.

We believe that the next logical step in our research program is to evaluate our most promising culture systems and techniques in prototype scale. Although these operations will be much too small to be profitable, they will be large enough to allow a meaningful evaluation of commercial feasibility.

Accurate data will be taken on the costs of labor, pumping supplementary heating, effluent treatment, foods, and other factors. These data cannot be obtained reliably from our small-scale laboratory systems.

In cooperation with Warren Johnston's program at the University of California, Davis, the cost equations, data on growth, survivorship, and other pertinent factors will be incorporated into a cost-effectiveness evaluation. Data from our prototype operations will provide the more reliable cost information to be used in Dr. Johnston's computer model. More meaningful predictions concerning the economic feasibility of lobster farming should then be possible.

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Cooperating Organizations

David Aiken of St. Andrews Biological Station, New Brunswick, Canada

San Diego Gas & Electric Company, California

San Diego State University Foundation, California

Sea Grant Aquaculture Program of the University of California at Davis

Southern California Edison Company, Los Angeles, California

Development of a Commercial Aquaculture System for the Crab *Scylla serrata* (Forskal)

Newton Harrison

A study was undertaken of the breeding cycle of the crab, *Scylla serrata*, in order to develop a technologically simple and labor-inexpensive aquaculture system.

The portunid crab, *Scylla serrata*, has been studied under simulated natural conditions since August 1972, and from September 1974 under the auspices of the UCSD Office of Sea Grant. Scylla, which is found from the east coast of Africa to the Phillipines and Tahiti, appears to be a very desirable creature for aquaculture—tasty, hardy, able to live out of water for up to five days, euryhaline and eurythermal, and normally simple to ship and transport. We are able to induce mating by lowering the specific gravity from 1.025 to 1.020. Specimens have survived in the laboratory for up to 18 months in a self-contained system. During this period, two of the mated females berried in the lab—one laid viable hatch but the other died before the eggs matured. However, resources have not been adequate, in terms of either funds or personnel, to run enough populations through the system for adequate statistical evaluation of the data, so that the results are generally observational reportage.

Habitat and tank configuration

Both clay pots, broken in half and scattered along the bottom, and cinder-blocks have been used to establish habitats and protected areas, as the crabs were unable to burrow into the bottom of the tanks. Best results were obtained when the habitations were scattered around the perimeter of the tanks with the center left open and one side left free for pre-mating encounters. Except for the experiment with juveniles in 5-gallon aquaria, two tanks were used for all the experimentation; they were 6 ft x 20 ft x 3 ft and 8 ft x 10 ft x 3 ft, respectively. Full bottom filtration was established with supported gravel beds, and E-heim filters were used in addition. Artificial fluorescent Gro-Lux broad spectrum lights were used with the addition of incandescents on a 12 hr on-off cycle.

Behavioral studies

Cannibalism studies were particularly productive. At least seven populations now have stabilized for periods of up to six months with a 6-10 ft^2 average of bottom space per mature crab. The lower figures were arrived at with more complex habitats and a plethora of habitat choices per crab. We also found that in populations of 12 to 20 individuals, a dominant male emerged and an hierarchy became established among the males, although none appeared among the females.

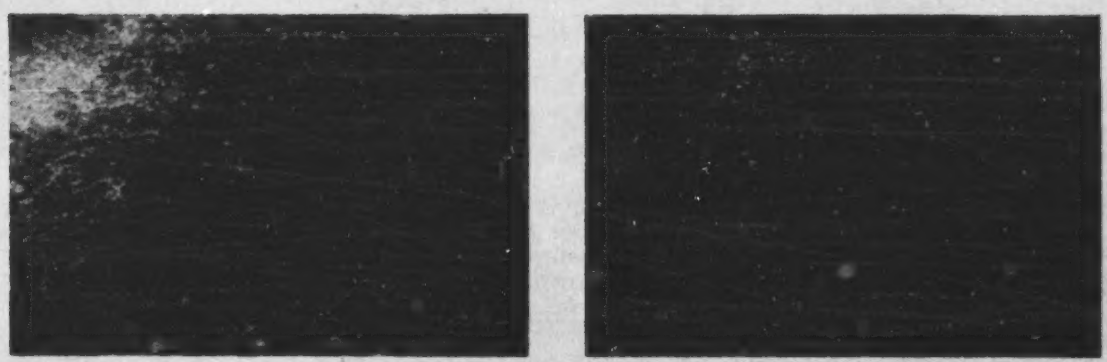
Mating dance

Mating

During the period 1974-75 there were five completed matings. All repeated the previously observed pattern (also reported in the literature) of a mating "dance" lasting up to several hours or more, in which male and female swim over and under each other, before the male clasps the female in the "prenuptial embrace" or protection which lasts up to 10 days until the female moults. Within 12 hours after moulting, the male again clasps the female, but this time with her underside facing him. They remain so for up to a week or 10 days, when he releases her upon completion of copulation.

Disease

Although there were numerous unexplained deaths, as opposed to deaths by cannibalism, the only disease organism that could be identified by Schapiro and Steenbergen was a chitinaceous bacterium.



Pre-mating protection

Our Sea Grant trainee also identified the presence of the barnacle, octolasmys, in the gills of several of the first moults of new specimens. Neither of these organisms should, under normal conditions, be responsible for the deaths of healthy individuals.

Growth rates

In three different populations scylla was grown from several ounces to 1½ pounds in eight to nine months in waters varying from 68 to 82°F. It was fed shrimp, smelt and squid, with kelp and crustacean carapaces added at intervals to the diet.

Problems

Research over the past year has been greatly inhibited by the difficulty of obtaining specimens. We strongly recommend that future research on Scylla be done on site or that a secure contract be established with several sources before starting experimentation. We also recommend that there be a closer study of the parameters of the natural habitat—temperature, salinity, food sources, etc.—for all stages of development, particularly the period of gestation. This may lead to better design of all artificial habitats. Another problem enocuntered was the disruption of the artificial 12-hr light cycle by the failure of a switching device. During this period the crabs refused to mate after the introduction of fresh water, began to reject food and appeared listless and inactive. Within two weeks after resumption of the normal light cycle, mating activity took place and to all outward appearances, all returned to normal. It is reasonable to assume from this that the crabs have established a circadian rhythm which it is important to maintain.

We conclude, nonetheless, that the potential for aquaculture for Scylla is high, the induction of mating is simple, and females can come to term in the tanks (although the precise parameters of this still have to be established). Eggs have been hatched and grown to maturity in the lab by both Brick in Hawaii and Ong in Malaysia. Thus, the basis has been laid for a more extensive group of researchers with a larger system to study more populations in parallel and finally bring the project to commercial readiness.

Copulation

Seaweed Resource Management

Santa Barbara
R/FA-10

M. Neushul and Dave Coon

For the past six years, Sea Grant supported studies have been carried out at UCSB on seaweed resource management. This study has been closely integrated with a continuing, basic research project on the growth and reproduction of benthic marine plants which began nearly 20 years ago at the Scripps Institution of Oceanography. Major contributions of the program have been: New approaches to the direct manipulation of highly productive coastal zone ecosystems; the provision of assistance and advice for individuals and groups; and the accumulation of hard data, essential for any rational assessment of Californian marine plant resources. All in all, the interaction of applied (Sea Grant) and basic (NSF) research programs has been very beneficial to both.

In the 1969 through 1970 initial period of this program, an economic analysis of the world seaweed industry was begun. This involved a considerable amount of library research and direct interviews, carried out by Drs. Wesley Silverthorne, P. Sorensen and others. With this information in hand, we established and ranked the various possible seaweed industries in California, and laid out a plan for their evaluation. Attention was immediately focused on the agar weed, *Gelidium*, because it had been harvested in California for a short time in the 1940's. Also, high grade pharmaceutical agar produced by the American Agar Company (from imported plants) is an important Californian product for which there is increasing demand. Studies were started of the growth of *Gelidium* and experimental harvests were conducted. Regrowth rates after harvesting were determined. Also, the germination and growth of sporelings were examined. Novel methods were developed for the "potting" and transplantation of *Gelidium* plants, and the groundwork was laid for further studies of *Gelidium*. A lengthy thesis on the optimal utilization of this resource has been accepted for publication by *Botanica Marina*, the international Journal. Also, the reproductive cells of the giant kelp, *Macrocystis*, were studied electronmicroscopically for the first time, along with other reproductive cells.

Experimental plantings

In the 1970 through 1971 period, experimental planting sites were established in Goleta Bay and adjacent to Campus Point near the UCSB Campus. These consisted of large concrete bars bolted together to form platforms. Substrates were attached to the platforms, and algal recruitment growth on these was followed. Studies of the agar weed, *Gelidium robustum*, which had been initiated in the previous year, were continued and expanded and a resource management study of this organism was further developed. Biological studies included germ cell production by *Macrocystis* and the effects of water motion on reproductive cell settlement and attachment. In order to study this process more effectively, a microscope which was adapted for use by divers under water was developed. As far as we are aware, this is the first time that completely submerged microscopy has been accomplished.

Development of equipment and methods

The 1971-72 period was largely spent constructing and developing environmental monitoring equipment to use with the offshore outplanting facilities. This consisted of a special light-sensing device, offshore buoys, anchors, chains, and related equipment for the monitoring of environmental conditions of water. We attempted to use Japanese rope line methods for the cultivation of *Laminaria* and *Gelidium*, and held meetings on the UCSB campus for members of the California industry groups to explain Japanese techniques and technologies to them. We also discussed our seaweed cultivation efforts with members of the Department of Fish and Game, and gave general public lectures and a television program on seaweed cultivation in Japan and the United States. A seaweed conference was attended by members of various University of California campuses and others, in which collaboration was discussed and a set of goals established.

In 1972-73 the *Gelidium* harvest model was completed and computerized. This was made available to Californian seaweed industries and the Department of Fish and Game. Work on a similar model for *Macrocystis* was started. We helped Mr. Nick Anderson (then a student at Cal. State Northridge) with his kelp bed model and began to directly study kelp productivity. The redesign and rebuild-

ing of a seawater-supplied greenhouse was completed so that high seawater flow rates could be used for kelp cultivation in the laboratory, making it possible to match laboratory conditions with those in the sea. This unique and effective facility is now being studied by the Japanese, and a similar unit will be built in the new Hokkaido laboratory. Our economic studies included estimates of the potential of *Laminaria* harvest in California, which turned out to be not economically feasible. Economic estimates also included those of several species of *Porphyra*, and one was selected for intensive study—*Porphyra nereocystis*, in its natural populations. Efforts were made to manipulate the life history stages in the laboratory, and testable samples of the wild crop were harvested and processed. Also, we purchased Japanese nori cultivation equipment (a floating net system) and laid the groundwork for collaboration with the Japanese on studies of *Porphyra*. We used our telemetry system to obtain real-time continuous light measurements at the cultivation site and presented these results at meetings in California. An *in situ* "seeding" of algal spores was attempted with limited success. We hosted a second statewide conference, this time jointly with others working in the mariculture area. Visitors from France, considering the transplantation of *Macrocystis* into the Atlantic Ocean, spent time with us, and there were year-long visits from two representatives supported by the Mexican government and one representative from Italy.

Harvesting estimates

The 1973 through 1974 period represents one in which more emphasis was placed on the *Porphyra nereocystis* standing crop estimates. This marine plant has never been harvested in California and so trial harvests were carried out as well as additional estimates of the value of this resource. Some preliminary management guidelines for improving yields were also established. In addition, experimental harvests of *Macrocystis* were started. This was possible because of the contributions made by the California seaweed harvesting companies and their generous allowance of the use of their harvesting vessels. This is an essential component, of course, for any *Macrocystis* crop monitoring and optimum resource utilization model. the percentage of the standing crop harvested was estimated and, using aerial photography, the initial canopy regrowth rates were determined. We also used an experimental "hydrodynamic aquarium", called a "water tunnel", to measure photosynthetic rates both in the laboratory and in the field under a variety of light and water motion conditions. New and improved sensing elements were added to our spar buoy-based telemetry system. Two papers were presented on this system at scientific meetings.

During the 1973-74 period, an invitation was extended to the International Seaweed Symposium Committee to hold the 1977 Symposium in California at UC Santa Barbara. This invitation was accepted. The committees for the Ninth International Seaweed Symposium, to be held at Santa Barbara, were called together; the International Advisory Committee came from its various member countries to meet there, and the initial organization of this Symposium was completed.

Book project

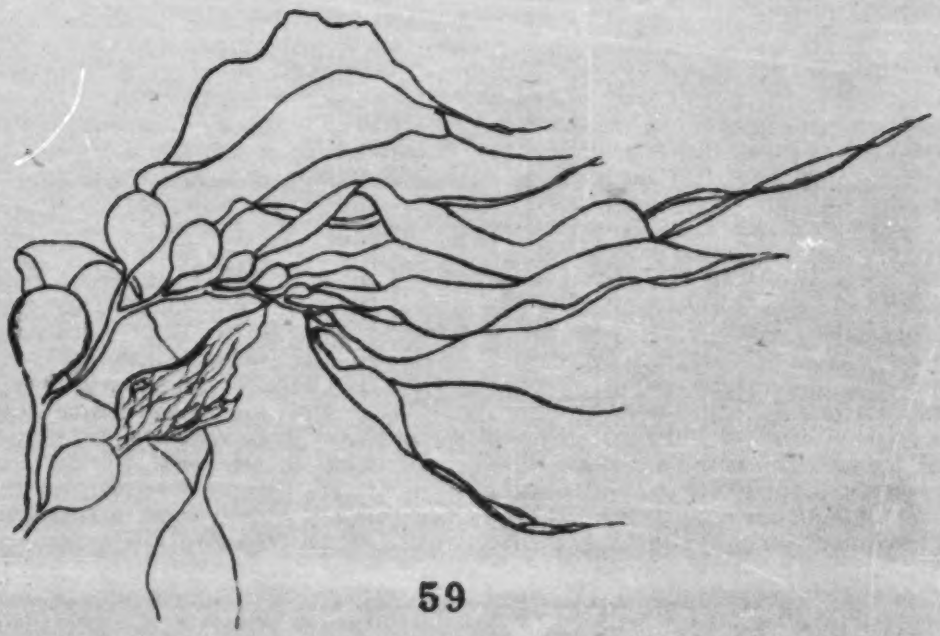
The 1974-75 period was one in which an attempt was made to pull together the various aspects of work over the past five years. We had previously been approached by M.I.T. Press and asked to submit the outline for a book on seaweed resource utilization, and are still working on such a project. We are exploring the possibility of a long-term "consortium approach" to studies of nearshore communities and associated organisms, and made plans to do this and are collaborating with several research groups in California on the planning of such a program.

Biological studies carried out during the 1974-75 period involved the use of our transplantation of experimental fouling plates and further studies of larger macroscopic life-history stages. Studies were continued on the controlled harvesting of *Macrocystis*, with aerial photographs being used to compare the harvesting effects on the regrowth of canopies. We were also able to complete and use a large-scale water motion device based on our previous experience in producing small-scale water motion variations. This has proven to be extremely effective. *Porphyra* harvests were carried out in two areas along the central California coast, and depending upon location, plants were collected from between 23 and 63 per cent of the supporting *Nereocystis* plants. The trial harvests were timed, and this information was provided to Dr. Phillip Sorensen to be used in a cost analysis of the harvesting process. Dr. Sorensen, who worked with us during the summer of 1975, was able to determine the value of samples harvested the previous

December. He did this through conferences and testing sessions with Spiral Foods and Japan Foods in California. Samples were also sent to Mr. James Woessner for research on *Porphyra* in Japan. Unfortunately, we harvested during the peak biomass period rather than the peak taste and texture period and compounded this error by improperly storing the harvested *Porphyra*. Accordingly, our material was of low taste quality. We anticipate, in future harvests, having to pay particular attention to the quality of the harvested *Porphyra* and the methods of handling.

Conclusion

In summary, our work has led us to study Californian marine plants that can be harvested and used directly for food (*Laminaria* and *Porphyra*) and plants presently used for the production of algin (*Macrocystis*) and agar (*Gelidium*). We can now say a great deal about how to measure the natural conditions in the sea that influence these plants, as well as the impact of various harvesting strategies on them. We can also predict that genetic improvement is possible since we have isolated and cultured the sexual stages of *Macrocystis* and the microscopic stages of *Porphyra* and have produced genetically defined plants. Our most spectacular achievement has been the production of an intergeneric hybrid between *Macrocystis* and *Pelagophycus*.



Marine Ecology of the Central California Coast

William Doyle

Field and laboratory studies were made of the commercially important seaweed, the carrageenanophyte *Iridaea cordata*. Our objectives were first, to provide basic information on its growth dynamics in relation to environmental parameters; and secondly, to provide the necessary data for resource assessment and management for a mariculture program.

I. cordata is a dominant lower intertidal alga from central California to southern Oregon and produces large quantities (50-65% kg dry wt.) of high-quality carrageenan. The bulk of this natural product is currently imported to meet our present domestic needs.

Resource availability and growth dynamics

During 1974-75 we completed our analysis of *I. cordata* resource availability in open coast habitats of central California. Results indicate that total standing crop (dry weight) is fairly similar at different open coast sites, but exhibits definite seasonal fluctuations. Low crops occur during winter with peak crops in summer. Peak crop levels are comparable with those of the east coast *Chrondrus crispus*, an alga which is currently our only established domestic carrageenan source.

To measure *in situ* growth dynamics and the contribution of vegetative reproduction and effects of harvesting, we totally harvested experimental plots in a natural population down to the basal, perennial crusts and regrowth was followed for one year. Additionally, a successful tagging method was developed and used to follow the growth of 182 individual algae blades during a period of one year.

Experimental plots of *I. cordata* denuded to the perennating crusts in November produced standing crops by summer (9 months) and autumn (12 months) that were not significantly different from control plots from the untreated natural population. Therefore, harvesting appears to have little effect on the regrowth of these annual algal blades and vegetative reproduction from the basal, perennating crusts is a major contributing factor in growth of natural populations.

Growth rates calculated from harvesting data and from increase in surface area of tagged blades show that a burst of growth occurred in spring. This increase was positively correlated with increasing solar radiation levels and day length, but not with seawater temperature.

Those juvenile blades that began growth in late winter-spring have a much higher growth potential throughout the year than those beginning as juveniles at other times of the year. This suggests that growth in this alga is synchronous and may be controlled by one or more environmental factors, such as light.

Laboratory studies

Biochemical studies demonstrated that the gametangial (male and female) stages of *I. cordata* synthesize kappa-carrogeenan (with gelling properties that make it most highly prized by industry), while the tetrasporangial (diploid) stage produces lambda-carrageenan. These findings indicate that selective harvesting and mariculture of gametangial stages would be an important advance in the economics and management of this species.

Controlled experiments on *I. cordata* production rates and nitrogen-uptake kinetics indicate that photosynthetic rates are light-saturated at low intensities, and ammonium-nitrogen is the preferred nitrogen source. Maximum ammonium-nitrogen uptake rates occur with levels often in excess of local ambient seawater conditions, suggesting that nitrogen enrichment in a mariculture system would enhance production in this species.

Publications

Hansen, J.E., Studies on the population dynamics of *Iridaea cordata* (Gigartinacene, Rhodophyta), *Proc. Int. Seaweed Symp.*, Vol. 8, in press.

McCandless, E.L., J.S. Craigie, and J.E. Hansen, Carrageenans of gametangial and tetrasporangial stages of *Iridaea cordata* (Gigartinacene), *Canad. Jour. Bot.*, 53: 2315-2318 (1975).

Cooperating Organizations

Hopkins Marine Station, Stanford University, Pacific Grove, California
Marine Colloids, Springfield, New Jersey

Kelp Forest Ecology of the Central California Coast

John Pearse

Data are being collected on energy flow, population dynamics and ecological interactions within the kelp forests of the Monterey Bay region, in order to develop sound kelp harvesting strategies and manipulation of important grazers and predators for optimal utilization.

Most of our work is being done within the kelp forest of the Hopkins Marine Preserve off Pacific Grove, California. This kelp forest is within the established range of sea otters which are particularly important predators regulating herbivore densities. Studies there have concentrated mainly on the production of giant kelp, especially as a source of drift kelp which is a major energy base for animals within and beyond the boundaries of the kelp forest. Studies are also being done off Santa Cruz Point, Santa Cruz, California, outside the established range of sea otters, where large populations of sea urchins limit kelp production. Commercial exploitation of the sea urchin populations and the return of sea otters to this area both seem imminent; these events should have profound effects on the kelp forest, needing careful documentation.

Kelp production and disposition

The study of the energy flow in the giant kelp forest of the Hopkins Marine Preserve off Pacific Grove, California, was begun in the fall of 1973. The primary objectives of this study were to determine the role of the giant kelp, *Macrocystis pyrifera*, as an energy source to the kelp forest community and to examine the production and export of drift kelp as an energy source to other marine communities.

The 1974-75 period marked the second year of field data collection, including seasonal standing crop estimates and monthly production rates of attached and drift kelp, and seasonal export rates of drift kelp from the forest. Preliminary analysis of these data shows that the standing crop of attached *Macrocystis* varies seasonally and annually, and that these fluctuations are due to rapid growth and highly variable losses. Loss of attached kelp, which is roughly equivalent to production of drift kelp, reached a seasonal peak in the fall (see Fig. 1) and correlates with the intensity of local wave action. Approximately 50 per cent of the total annual net production of attached *macrocystis* was lost as drift kelp during 1974-75. Export of this drift kelp from the forest also correlates with water movement intensity. Therefore, during the season of highest drift production, most of the drift is exported. This must intensify the seasonal fluctuations in the supply of drift kelp received by other communities.

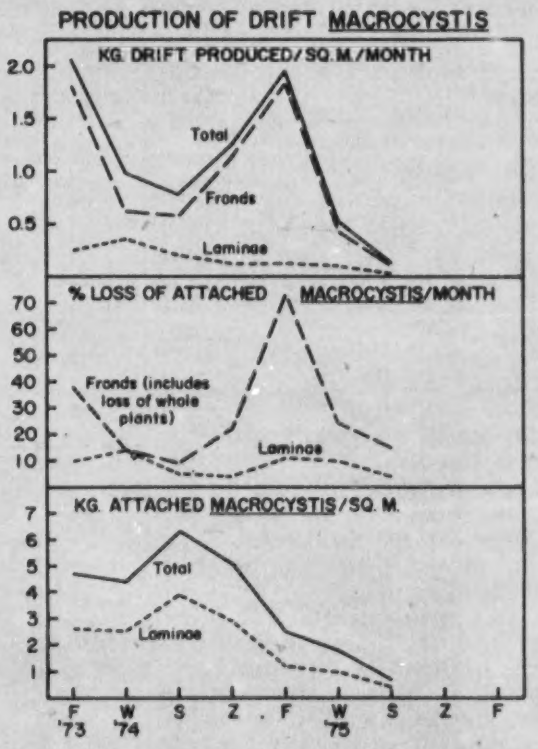


Fig. 1. Seasonal changes in attached kelp, loss of attached kelp and production of drift kelp in the kelp forest of the Hopkins Marine Preserve from the fall of 1973 through the spring of 1975

Santa Cruz Point studies

Monitoring of the sizes and numbers of major large plants and animals was done at four fixed stations off Santa Cruz Point for the second year in the summer of 1975. These stations extend from 50 meters within the kelp forest to 100 meters seaward of the kelp forest. No difference was found in the sizes or densities of the major plants and animals between the summers of 1974 and

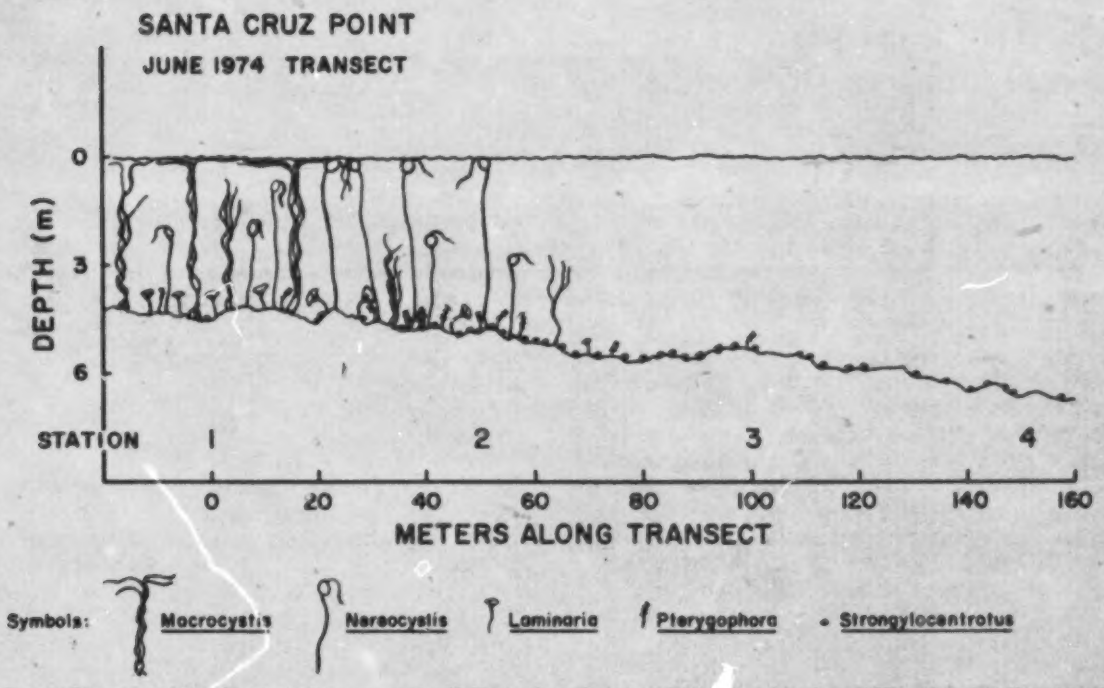


Fig. 2. Diagram of the fixed station transect off Santa Cruz Point as it appeared in June 1974, showing the abrupt transition between the inner kelp dominated zone and outer sea urchin-sea star dominated zone. No change was detected among these stations in sample counts done in the summer of 1975

1975 (see Fig. 2). The edge of the kelp forest was marked by high numbers of red sea urchins (about 60 per 10 m^2). High numbers of bat stars and sea stars were also found outside the kelp forest, while plant densities there were very low. The dense population of sea urchins at Santa Cruz Point, only about one and a half miles from the Santa Cruz Harbor, seems likely to be exploited commercially for human food in the near future. Moreover, by the end of the summer of 1975, about 20 sea otters were foraging less than 10 miles from Santa Cruz Point and they are expected to arrive in the Santa Cruz Point area within the coming year. Either commercial harvesting or heavy predation by sea otters should dramatically lower the sea urchin densities and will probably lead to increased kelp production and other changes which now can be documented.

Publications

Gerard, V.A., The role of drift algae in the energy flow through a Monterey Bay kelp forest. Paper presented at the symposium "The forest, the rivers, and the sea—an unbroken chain in the Pacific Northwest" of the Physiological Ecology Section of the Ecological Society of America, Corvallis, Oregon, 21 August 1975.

Pearse, J.S., An echinoderm dominated area adjacent to a giant kelp forest off Santa Cruz, California. Paper presented at the 55th Annual Meeting of the Western Society of Naturalists, Vancouver, British Columbia, 27 December 1974.

Shanks, A., J. Mattison, J. Trent, and T. Akin, A study of the movement of a subtidal sea urchin. Paper presented at the 55th Annual Meeting of the Western Society of Naturalists, Vancouver, British Columbia, 27 December 1974.

Cooperating Organizations

California Academy of Sciences, San Francisco, California

Hopkins Marine Station, Stanford University, Pacific Grove, California

Salt-Tolerant Plants: Problems and Potentials

Emanuel Epstein

Based upon the established fact that salt tolerance in barley and tomatoes is an heritable trait, progress has been made in adapting these crops to saline conditions through appropriate selection and breeding. The aim of this research and development is to make seawater and the huge reservoir of inorganic nutrients contained in it available for crop production.

Most crop plants are unable to tolerate even modest concentrations of salt in soils and irrigation waters. When roots of many crop species are exposed to salt concentrations no higher than 1/20 to 1/12 of the concentration of seawater, the plants suffer. Yet there is irony in this situation. Seventy per cent of the surface of the globe is covered by the sea, with a salt concentration of about 3.5 per cent. And all the life in this highly saline habitat ultimately depends on green plants: the algae, collectively called "phytoplankton," which, like land plants, trap the energy of sunlight and synthesize from seawater and the inorganic nutrients dissolved in it the proteins, carbohydrates, fats, vitamins and other constituents essential for their own growth—and that of their animal consumers. This recognition—that there is no basic biological incompatibility between salinity and plant life—forms the rationale for the present project of creating salt-tolerant crops.

Barley

As mentioned in last year's Annual Report, varieties or strains of barley differ in their ability to tolerate saline conditions at different stages of their life cycle. These findings raised the crucial question whether resistance to saline conditions is a genetically controlled trait, because heritability is an indispensable condition for breeding varieties of barley combining the highest possible degree of salt tolerance at all stages of the life cycle.

The question raised has been answered in the affirmative. This was found in experiments in which contrasting lines of barley were crossed and the yield of the progeny, in terms of weight of seeds per plant, was measured through the fourth generation, the salinity stress corresponding to 44 per cent of the sodium concentration of seawater. The ability of barley to yield under salt stress was found to be under genetic control; hence it can be improved by incorporation of germ plasm from salt-tolerant domestic or wild strains.

Tomatoes

The available varieties of the commercial tomato, *Lycopersicon esculentum*, were found not to differ appreciably in salt tolerance, which was not high. As mentioned in the last Annual Report, we obtained seed of another species of the tomato, *Lycopersicon cheesmanii*, which grows wild in the Galapagos Islands. Some strains of this plant were very salt-tolerant, and interfertile with the commercial species. This led us to suggest that salt tolerance from the wild *L. cheesmanii* might be bred into the conventional tomato. This possibility has now been realized. Flowers of the commercial-type tomato, variety VF 36, were pollinated with pollen of the Galapagos species, and pollen of the progeny was then used to pollinate the commercial type—a procedure called "backcrossing." This same procedure, repeated several times, resulted in a progressive increase in the salt tolerance of each successive generation. The tomatoes of our best genetic lines are the size of conventional cherry tomatoes or larger.

Left: Three fruits of the salt-tolerant Galapagos species of the tomato, *Lycopersicon cheesmanii*; right: fruit of the commercial-type tomato, *L. esculentum*; middle: two fruits of second-generation experimental progeny of the two parent species

Plant material is now at hand that is far more salt-tolerant than any commercial varieties we have tried. Our best selections are to be tested at the Bodega Marine Laboratory in the spring of this year, using various dilutions of seawater, as in the experiments planned for barley. A picture of the parent lines and some experimental progeny is shown in the Figure.

Characterizing salt tolerance in plants

Various physiological tests were carried out, including the absorption and distribution of sodium, potassium, and chloride in the salt-sensitive commercial-type tomato and the salt-tolerant Galapagos Island species already referred to. In several of these features, the two species behave in diametrically opposed fashion. It is hoped that tests of this kind can be used as rapid indices of salt tolerance. They also may give us some understanding of physiological mechanisms that make for salt tolerance.

News items concerning our work appeared in *BioScience*, vol. 25, No. 6 (June, 1975), p. 400, and in several other publications (*Christian Science Monitor, New Scientist, Die Welt* and others). The British Broadcasting Corporation carried an interview with Mr. J. D. Norlyn and Mr. D. L. Fredrickson about this project.

Publications

Frederickson, D.L. and E. Epstein, Genetically controlled differences in salt tolerance of two species of the tomato, *Plant Physiol.*, 56(2) Suppl., p. 4 (1975), Abstract.

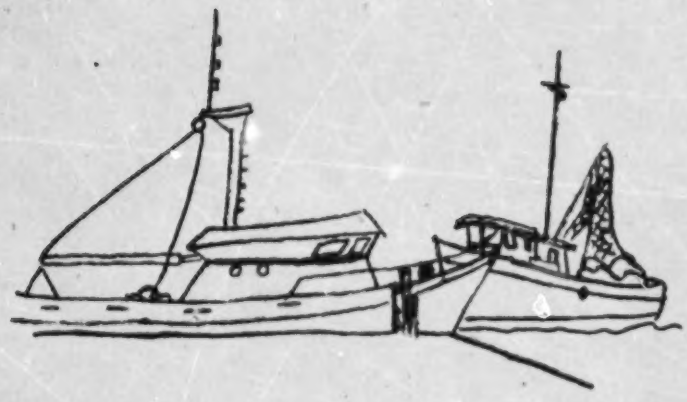
Norlyn, J.D., and E. Epstein, Salt stress during the life cycle of barley cultivars, *Ibid.*, 56(2) Suppl., p. 4 (1975),Abstract.

Rush, D.W., and E. Epstein, Effects of salinity on *Lycopersicon esculentum* and *L. cheesmanii*, *Ibid.*, 56(2) Suppl., p. 4 (1975), Abstract.

Cooperating Organizations

Bodega Marine Laboratory, California

U.S. Department of Agriculture, Divisions of Agronomy and Vegetable Crops



FISHERIES

Recognizing that fish stocks are finite and in many instances diminishing, we have studied the utilization of an apparently underutilized species, the management of species subject to increasing pressures of exploitation, and the improvement of processing technology to increase the marketability of several species.

Our Sea Grant research includes studies of an apparently underutilized food resource, *Loligo opalescens*, a species of squid common to Monterey Bay, to determine its trophic relationships and whether or not expansion of its fishery is desirable and feasible. Two other projects examine the ecology and management of the expanding and relatively new sea urchin fishery, while a fee-assessment strategy to assist in the management of the high-seas yellowfin tuna fishery has been the subject of study by an economist. Still another group of projects deals with improving the technology of preparing wholesome and attractive sea food for market.

The California Market Squid Fishery

Moss Landing
Marine Laboratories
R/F-15

T. W. Thompson and H. W. Frey

Methods are being sought for increasing the harvest of squid, including better information on squid spawning. Other objectives in this study are: to determine acceptable levels of harvest to ensure that squid are utilized on a sustained yield basis; to determine the impact of an increased harvest of squid upon other living resources of the California Current; and to investigate, in the more distant future, the potential of other squid species for new fisheries in the California Current system.

The first year of this three-year project was designed as a survey phase to test techniques, determine the feasibility of different approaches, and collect data upon which a routine could be established. The project has been divided into five subject areas.

(1) Squid Productivity

Project Leaders: T.W. Thompson and H.W. Frey; Associate: J.R.R. Ally

The major task in this area of this group is to investigate for utilization by management agencies various methods of estimating population size and locating new potential fishing grounds, and to assist the industry with development of more efficient means for locating and taking squid.

In this effort, two month-long exploratory fishing cruises for market squid were carried out aboard California Department of Fish and Game's research vessel *Alaska*. The first of these cruises covered the coast from La Jolla north to Santa Cruz in 1974, and the second from Monterey to the Oregon border in 1975.

The results of the first cruise have been published in a Sea Grant Technical Report (Ally, Evans and Thompson, 1975). This expedition was highly successful, proving the feasibility of employing night-lighting and the Japanese squid jig in locating and sampling spawning concentrations of *Loligo opalescens*. A result of the employment of this technique was the detection of three heretofore little known areas of potential commercial significance for the squid fishery: Cape San Martin to Partington Point; Pfeiffer Point to Point Sur; and Yankee Point to Pescadero Point (Carmel Bay).

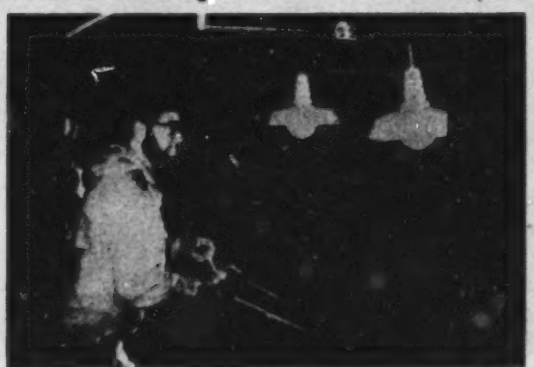


Fig. 1. Night-lighting and jigging for squid under the lights. MLML graduate student Ron Evans tries his luck

A second sampling technique was tested on the first cruise; this involved surface tows with a large midwater trawl (30 m mouth). The trawls took animals of a variety of size classes, from 20 mm to 148 mm. This was an important step forward since studies of squid as predators depend on a reliable means for taking non-spawning animals. This method of capture will also be of importance in providing specimens for the reproduction and age determination group.

Whereas the squid jig appeared to be selective for adult males, the trawl was not. The ratio of male to female squid taken on the jigs was 7.68:1, whereas the trawl took animals in the ratio of 1.5 males to every female. Although smaller animals appeared to be attracted to night-lights, we have been unable to take juvenile squid on the Japanese jigs.

The 1975 cruise results are presently being analyzed. Bad weather conditions and a poor year for the squid fishery statewide are reflected in a low number of squid sightings, few captures by jig, and small numbers of animals taken by trawl. This cruise, which surveyed waters off central and northern California, may have been conducted too early in the year. It is more likely, however, that the relatively small number of squid observed and taken reflects a general scarcity of spawning animals during 1975.

(2) Population Structure

Project Leaders: J.R.R. Ally and J.P. Christofferson

Information on population structure will be important in determining whether squid

can be managed on a statewide basis or must be treated on the basis of individual fishing grounds. Two approaches have been employed in analyzing population structure.

The first involved standard morphometric analyses—dorsal mantle length, fin length, fin width, mantle thickness, and ratio of fin length to dorsal mantle length. This study employed squid sampled from the commercial catch in Monterey, Moss Landing, San Pedro and Port Hueneme during 1974. Statistical analyses based on 2424 animals indicated that at least two geographically localized populations of squid occurred in the California catch, one in Monterey Bay and one in southern California. However, the differences revealed by standard morphometrics were not sufficiently marked to establish the existence of subspecies or genetically isolated populations.

The second approach involved biochemical investigation. This year the goal was to determine the feasibility of electrophoresis as a tool for identifying genetic isolation, should it exist. Studies included experiments with more than 23 different enzyme systems. Polymorphism was discovered in two enzyme systems, the acid phosphotase esterases and phosphoglucomutase, as well as in the blood proteins, proving that electrophoresis can be a practical tool for this work.

(3) Reproduction and Age Determination

Project Leaders: R.D. Beeman and J.D. Spratt

Statistical analyses of squid taken from the market catch in both Monterey and southern California demonstrated the existence of three distinct size classes. These data, however, were insufficient to establish whether the classes represented year or half-year age groups. Microscopic observations of the hard parts of the squid revealed growth increments in the beak, the pen and the statolith. The statolith appears to be the most promising organ for age determination, and techniques have been developed for processing it so that growth rings may be counted.

The process of squid spermiogenesis has been studied with both light and electron microscopes and the structure of the sperm cell elucidated. Methods have been evolved to use autoradiography in determining the length of time required for the development of sperm cells.

Production of male gametes was studied intensively during the first year. Detailed microscopic examinations of 25 squid, ranging in size from 96 mm to 139 mm dorsal mantle length, disclosed that all animals were sexually mature. This is a surprisingly large size range. A second observation was that the cellular divisions leading to production of mature sperm are almost totally synchronous. In the testes of the animals studied, only the late stages of spermatogenic cells were found. This developmental process is quite distinct from that characterizing the testes of many vertebrates and invertebrates, where a stratified epithelial layer gives rise to maturing sex cells in waves, replacing expended sperm cells. The male *Loligo opalescens* appeared to have a definite period of time in which it was sexually productive. There is no evidence of new germ cell proliferation in spent animals, reinforcing the hypothesis that male squid are capable of spawning only once in their life cycle.

(4) Oceanography

Project Leader: W.W. Broenkow

The oceanography group employed both biweekly sampling and an intensive cruise to study the hydrographic conditions which prevail in Monterey Bay, especially over the squid spawning grounds.

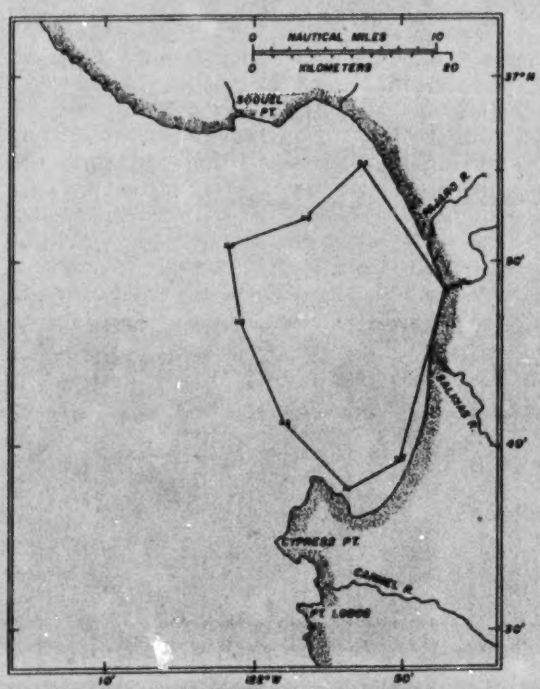


Fig. 2. Cruise track of biweekly hydrographic observations and station locations.

Biweekly cruises involved water sampling at seven stations (Fig. 2), occupied in conjunction with night-lighting for squid. Samples were taken at standard depths from the surface to the bottom for a routine suite of chemical and physical parameters. The results of the first six months of the sampling program were published in the Sea Grant Technical Report (Broenkow, Lasley and Schrader, 1975).

During the year a sophisticated system for horizontal and vertical profiling of conductivity, temperature, chlorophyll and turbidity was assembled. This system, which interfaces with a programmable calculator, was employed during an intensive six-day study of the waters over the spawning grounds of the Monterey Peninsula in August 1975. While results are still undergoing analysis, strong station-to-station and day-to-day changes were noted which suggest the presence of thermal fronts in the area such as those hypothesized by Japanese researchers to be associated with fishable concentrations of non-spawning squid.

Catch and fishing effort data for the years following 1960 have been assembled and collated together with oceanographic conditions for those years. Oceanographic data have been compiled from CalCOFI hydrographic observations, Bakoun's upwelling index, and, during the latter years, local winds. Preliminary analysis of these data shows a seasonal peak in catch/unit effort associated with the well-documented seasonality of the wind field, surface temperatures and development of the thermocline. Details of these relationships are being quantified by cross-correlation analysis.

In conjunction with the population structure morphometric analysis of commercial catch data for 1974, a pronounced peak in spawning activity during the dark of the moon became apparent. This peak was reflected not only by an increase in the number of size classes taken by commercial fishermen, but also in the number of spent animals appearing shortly after the moon was dark. It has long been the fishermen's contention that squid fishing was not profitable during the full moon period, and this evidence seems to support their observations.

(5) Food Chains: Predators

Project Leader: G.V. Morejohn

Vertebrate predators of squid were collected during every month possible from

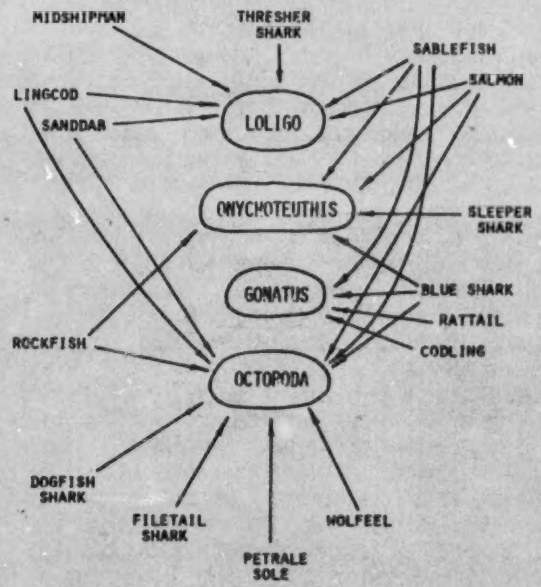


Fig. 3. Fish predators of cephalopods

September 1974 through August 1975. Marine mammals, completely protected since 1972, were available as dead specimens washed up on beaches, while birds were taken with shotgun and fish by gill net, otter trawl, midwater trawl and hook and line. In addition to these collection efforts, the group was substantially assisted by local commercial fishermen who provided gastrointestinal tracts of commercially important fishes.

Five species of sharks and nine species of teleost fishes (including ling cod,

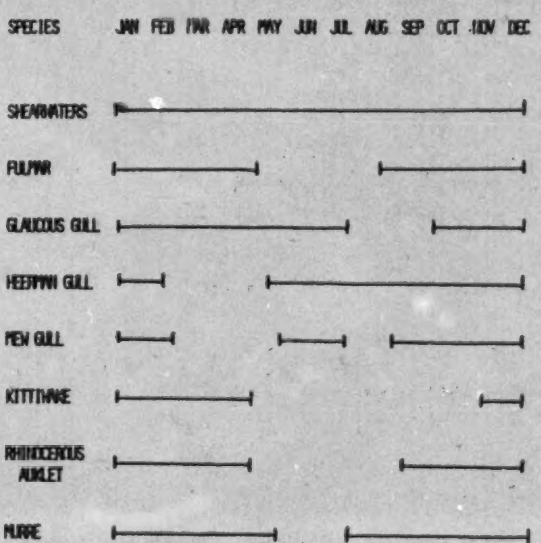


Fig. 4. Major marine bird predators in Monterey Bay seasonally

rockfish, salmon, sablefish and dover sole) were found to feed upon squid (Fig. 3). While many marine birds are year-round residents in Monterey Bay, the majority are transient migrants, occurring seasonally, especially during fall, winter and spring (Fig. 4). Twenty six marine bird species were found to feed on *Loligo*, 22 transient migrants and four residents (Fig. 5). Six species of marine mammals (including the elephant seal, Alaskan fur seal, California sea lion, striped dolphin, harbor porpoise, Dall's porpoise, and the California sea otter) feed on *Loligo* (Fig. 6). The California sea lion is a particularly heavy squid feeder present in great abundance in the bay during certain portions of the year.

It is significant that the migratory fish, birds and mammals are the greatest consumers of squid. Evidence of potential conflict in marine resource development and management of other commercial fisheries seems at present to involve primarily sablefish and salmon both of which are heavy squid consumers.

Predator researchers also observed that squid of all sizes may be found in

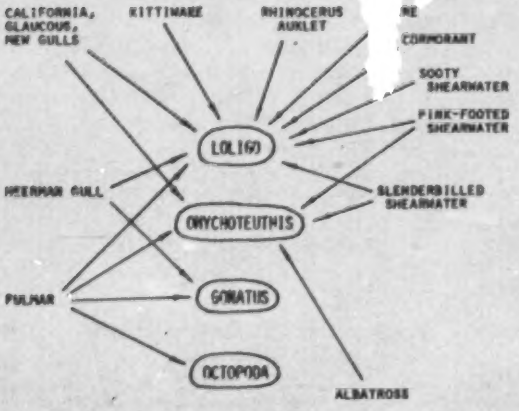


Fig. 5. Bird predators of cephalopods

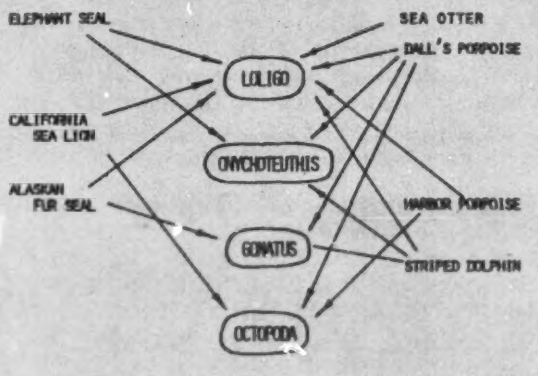


Fig. 6. Mammal predators of cephalopods

Monterey Bay throughout the year. Specifically, they noted that they occurred under feeding bird aggregations at the water's surface in daylight (these squid were feeding upon euphausiids). These findings are particularly significant in light of the fact that the whereabouts and behavior of juvenile market squid have heretofore been little known. Feeding squid were previously believed to be active in surface layers of the ocean only during hours of darkness.

Publications

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Paper on the results of the squid exploratory fishing cruise presented by T.W. Thompson at Annual Meetings of Western Society of Naturalists at Vancouver, British Columbia, December 27-30, 1974.

Cooperating Organizations

California Department of Fish and Game, Long Beach and Monterey, California
California Marine Research Committee
Southwest Fisheries Laboratory, National Marine Fisheries Service, Terminal Island, California

Mass Culture of Toxic Dinoflagellates

Francis Haxo

The unavailability of a reliable laboratory supply of red tide dinoflagellates of known or suspected toxicity has hampered elucidation as to which ones are toxic, the chemical nature of their toxins, and the further development of specific chemical tests for these toxins and their masked forms.

Our efforts during the second year of funding emphasized the laboratory culture of red tide dinoflagellates in order to provide a reliable source of algal material for toxin studies by Dr. H. Rapoport. Objectives have been to screen a variety of such bloom dinoflagellates for toxicity and saxitoxin content; to further the development of a specific and sensitive test for saxitoxin which would be effective on algal as well as animal sources; and to provide sufficient *Gymnodinium breve*, the Florida red tide organism, to extend studies on the isolation, purification and structural determination of its toxic components. Preliminary studies on the physiological characteristics of a La Jolla isolate of the toxic "*Gonyaulax catenella*" have also been undertaken.

The results of the toxin screen, tabulated below, do not confirm the presence of toxins (or saxitoxin, as such) in several suspect species. Since *Gonyaulax polyedra*, *Prorocentrum micans* and *Gymnodinium splendens* may occur in monospecific blooms in southern California waters, the negative findings for these species are of interest in future consideration of the geographical and temporal constraints of shellfish moratorium policy in California.

In this context, the dinoflagellate causing paralytic shellfish poisoning in the northeast Pacific, *Gonyaulax catenella*, occurs in small numbers off the southern California coast primarily during winter and spring months. It may be a rare southerly intruder or represent a distinct strain adapted to warmer waters. Preliminary results of experiments designed to test the light and temperature growth responses of a La Jolla isolate (identity as *G. catenella* not fully confirmed) indicate some physiological differences when compared with results reported in the literature for *G. catenella* isolated from colder waters of northwestern Washington. The La Jolla isolate appears to show somewhat higher temperature and light optima than the

Summary of Dinoflagellate Harvests—Laboratory Cultures and Natural Blooms

Species	No. of Lots	Amt. harvest (l)	Cells/ml	Wet Wt. (g)	Dry Wt. (g)	Toxicity	Origin of Material
Prorocentrum micans	1	31.0	1.34×10^4	9.80	1.80	-	La Jolla
Gymnodinium splendens	1	15.5	3.61×10^3	7.60	0.95	-	La Jolla
Peridinium foliaceum	1	17.0	3.88×10^4	11.40	2.72	-	Puerto Rico
Amphidinium carterae	1	17.0	1.47×10^6	10.80	2.52	-	Woods Hole
Gonyaulax tamarensis 173a	1	10.0	9.92×10^3	6.50	0.70	-	Plymouth
Gonyaulax tamarensis	1	15.0	4.32×10^3	2.80	0.22	+	New England
Gonyaulax excavata	1	15.5	1.48×10^4	4.35	0.68	+	British Columbia
Gonyaulax acatenella	1	15.5	8.30×10^3	3.60	0.32	-	British Columbia
"Gonyaulax catenella"	4	238.7	1.32×10^4	37.25	7.08	+	La Jolla
Gonyaulax polyedra	1	15.5	1.88×10^4	9.20	0.80	-	La Jolla
Gonyaulax polyedra 70a	1	15.5	2.03×10^4	8.10	0.58	-	Santa Barbara
Gonyaulax polyedra 73	1	14.0	2.21×10^4	5.00	0.57	-	Santa Barbara
Gonyaulax polyedra	1	23.5	2.68×10^4	11.80	2.20	-	Santa Barbara
Gonyaulax polyedra natural bloom (night collection)	1	--	3.84×10^3	11.80	1.96	-	La Jolla
Gonyaulax polyedra natural bloom (day collection)	1	--	3.72×10^3	16.80	2.84	-	Huntington Beach
Gonyaulax polyedra natural bloom (day collection)	1	--	2.83×10^3	14.20	2.20	-	La Jolla

northern form and there is the further indication that it may have a more restricted lower temperature tolerance. Further studies are needed, however, to verify these points and to evaluate their significance.

Since physiological data reported for *G. catenella* are relatively scarce, we report here some features of the La Jolla isolate: chlorophyll *a* content, ca. 10 $\mu g/10^6$ cells; respiration rate, 23.4 $\mu l\ O_2/hr/10^6$ cells; photosynthesis rate (corrected for respiration) 58.6 $\mu l\ O_2/hr/10^6$ cells; photosynthesis/respiration ratio, ca. 2.5. Measurement conditions were 18°C, non-limiting CO_2 and a saturation light level of 2000-3000 $\mu watt/cm^2$. Cell growth was good in both continuous illumination and 12:12 light-dark cycle. In the range of optimal growth conditions (on GPM medium, 900 ft-c., 18.5-20°C) 0.7 to 0.8 cell divisions/day were observed. Maximum cell densities of 35,000 cells/ml were achieved in GPM medium at 600-1200 ft-c. and 16°C.

Having determined the tolerance and optimal growth ranges, experiments are in progress to determine the effects, if any, of light, temperature and culture age on toxin production. Cells have been grown under a variety of conditions and are currently being assayed in Berkeley for toxicity and saxitoxin content.

Mass culture of the Florida red tide organism has continued during the fiscal year. Our previous experience with this fastidious organism and the refinement of mass culture techniques have assured regular and reliable harvests. During 1974-75, 10 lots totaling over 1500 liters yielded 22.6 grams of lyophilized cells. The apparent absence of peridinin in this organism, when grown under standard growth conditions, was also observed in cells grown at very low light levels. Further features of the unusual *G. breve* pigmentation were examined and the *in vivo* absorption spectrum of whole cells was determined.

Our work with the dinoflagellates has been carried out in collaboration with Dr. H. Rapoport, who has undertaken all of the toxicity tests and toxin studies of the algae made available from our laboratory.

Publications

Assistance was given to the U.S. Navy Department in the film production "The day the tide turned red." A print is available at Scripps.

Cooperating Organizations

Institute of Marine Resources, La Jolla, California

Optimal Management of Sea Urchin Fisheries

San Diego
R/F-18

Paul Dayton and Mia Tegner

In the relatively short period of four years, the harvest of the previously unexploited red urchin, *Strongylocentrotus franciscanus*, has grown to a fishery of over six million lb/yr. This project aims to determine the important population parameters necessary for managing a sustained yield fishery and to protect this important member of the nearshore benthic community from overexploitation.

This year we have censused the Pt. Loma kelp bed to assess the standing crop of both red (*S. franciscanus*) and purple (*S. purpuratus*) urchins with the help of divers from the California Department of Fish and Game and San Diego State University. Permanent study areas were established to encompass a range of habitats where animals can be followed for extended periods of time. These study populations are monitored for age structure, recruitment, growth, natural mortality, and fecundity.

To understand the response of wild populations of sea urchins to fishing pressure, we need to determine the reproductive potentials of the exploited and nonexploited size classes, the patterns of recruitment of juveniles from the plankton and into various size classes, and growth rates. Our data on the commercial catch of red urchins from the Channel Islands and mainland near Santa Barbara indicate that 95 per cent of the catch consists of animals between 95 and 131 mm in diameter; animals smaller than 95 mm and larger than 131 mm are left to contribute their gametes to the next year class. Red urchins from Pt. Loma were found to begin releasing gametes at a size of about 45 mm. We are attempting to determine relative fecundities of all size classes by looking at gonad indices and volume of egg output. With these data we can compute the effect of the fishery on the reproductive potential of the whole population.

Sea urchin recruitment

Last year was a good year for urchin recruitment in our study areas, enabling us to learn a great deal about the natural history of this important stage in the life cycle. Small purple urchins can be found in a variety of habitats: in kelp holdfasts, in coralline algae, in cobble beds, under rocks, or under adult urchins. Small red urchins are far less versatile; they are generally found only under the spine canopies of the adult red urchins. This spine canopy appears to offer protection from predators to small urchins of both species as well as numerous juvenile red abalone. The young may also benefit from scraps of food snared by the adult urchin. This behavior pattern has important implications for the fisheries, because the harvesting of adults is removing nursery grounds as well as reproductive potential. Our experimental fishings conducted at Pt. Loma study sites have confirmed this hypothesis; fewer juveniles are found with respect to control sites after urchins of the 95-130 mm size class are removed.

Fears of overexploitation

Sea urchins, especially the purple urchin, are an important laboratory organism for the study and teaching of developmental biology. Scientists in this field are concerned that the commercial fishery will overexploit red urchin populations and then eliminate their resource. The current fishery is only taking red urchins, and the harvest procedures (dictated by economic constraints) leave so many urchins behind that this species appears to be in no danger. The economic status of the fishery precludes harvesting and processing of the smaller purple urchin now and in the foreseeable future. A short report on this subject is being prepared for distribution by the Advisory Services to help resolve the controversy.

Cooperating Organizations
California Department of Fish and Game, San Diego, Long Beach and Sacramento, California
Kelco Company, San Diego, California
Local fishermen
National Marine Fisheries Service, La Jolla, California

The Effect of Fishing Sea Urchins on the Marine Ecosystem

Santa Barbara
R/F-19

Joseph H. Connell and Stephen Schroeter

The recent advent of an extensive sea urchin fishery in southern California has raised at least two interesting questions: What harvesting practices should be employed to maximize the yield of sea urchins? How will the harvesting of large quantities of sea urchins affect the structure and dynamics of the kelp bed community? Depending upon their answers, it may be possible to establish a sensible fishery management policy.

The first of the above stated questions is being studied most intensively by Dr. Paul Dayton, while for our part we are attempting to answer certain aspects of the second one. Specifically, we are trying to determine whether removal of the red urchin (*S. franciscanus*) will significantly affect the distribution and abundance of its possible competitors or its food (*Macrocystis* sp.). Destructive overgrazing of kelp forests by three species of sea urchins (*S. franciscanus, S. purpuratus,* and *Lytechinus* spp.) has been documented for some areas in southern California (Leighton, 1971). This finding has given rise to the commonly held view which equates selective removal of the red urchin (*S. franciscanus*) with the removal of all urchin species, thereby maintaining that such a program will lead to restoration of large areas of kelp bed habitat. This somewhat simplistic view ignores the value of maintaining sea urchins as an exploitable resource and does not consider the effects that such removals may have on other members of the kelp bed community.

Thus, while it is likely that removal of red sea urchins will result in increases of algal standing crop in some areas, our studies indicate that it is also likely to lead to an increase in the purple sea urchin (*S. purpuratus*), for two reasons. First, sampling and experimental data show that red urchins are probably superior to purple urchins as space competitors. Secondly, preliminary observations indicate that purple urchins are equally or more destructive to kelp beds than red urchins. Therefore, the ultimate result of a selective removal of red urchins may be an increase rather than a decrease in grazing pressure. Another potentially important effect of removing red urchins on the community is the loss of the habitat essential to the young of commercial species. Large red urchins shelter both young urchins and abalones beneath their oral surfaces; removal of this habitat by extensive fishing pressure could lead to reduced recruitment of both groups.

Urchin distribution and competitive interactions

The distribution and abundance of adult and juvenile red and purple urchins were studied in mid- and low intertidal tide pools on the west end of Santa Cruz Island, and at a low intertidal boulder field on the south side of Santa Cruz Island. The density of adult and juvenile *S. purpuratus* is significantly greater in higher than in lower pools, while it is the reverse in adult and juvenile red urchins. These data suggest that competition with *S. franciscanus* may be responsible for the lower density of *S. purpuratus* in low intertidal tide pools.

Sampling at another location on Santa Cruz Island (a shallow subtidal boulder field at Willows Anchorage) has shown that red urchins occupy the bases of boulders, while purple urchins occupy the less desirable boulder tops. (Boulder tops are less desirable habitats than their bases for two reasons: they are exposed to air at extreme minus tides, while the bases are not; and they are less likely to trap drift algae than areas around the bases because of their convex shape.) These data also suggest that competition with *S. franciscanus* affects the distribution of *S. purpuratus*. To test whether this distribution pattern was caused by competition, red urchins were removed from the bases of some boulders, purple urchins were removed from the tops of other boulders, and red urchins were removed and replaced from the bases of other boulders (the last manipulation controlled for any handling effects).

These manipulations yielded the following results: Purple urchins moved down from the tops of boulders when red urchins were removed from around their bases. Red urchins remained at the bases of boulders on rocks where purple urchins were removed

from the tops. Finally, controls showed no significant changes in the distributions of either red or purple urchins. These results strongly support the hypothesis that red urchins are better space competitors than purple urchins.

Laboratory experiments, conducted to determine the mechanism of competition, showed that red urchins were able to displace purple urchins of the same test diameter from grazing sites (small discs of *Macrocystis* sp.), while the reverse did not occur. The reason for this is that red urchins have longer spines than purple urchins of the same test diameter. If a red and a purple urchin of the same test diameter come into contact when attempting to graze on a limited amount of food, they begin to fence with their spines. The red urchin, because of its longer spines, is able to touch the epithelium covering the test of the purple urchin, but the shorter spines of the purple urchin cannot touch the epithelium covering the test of the red urchin. In many cases, this mechanical irritation by the spines of the red urchins either caused purple urchins to move away from grazing sites, or prevented purple urchins from moving onto grazing sites occupied by red urchins.

Relative effects of red and purple urchins on kelp

Two sorts of preliminary data suggest that purple urchins are equally or more destructive to kelp than red urchins. First, tide pools at Santa Cruz Island that have only red urchins have significantly more macroalgae (*Eisenia* sp., *Egregia* sp., and *Macrocystis* sp.) than tide pools composed only of purple urchins. Second, *Macrocystis* holdfasts collected near Pt. Loma contain significantly more purple than red urchins. Leighton (1971) reported that urchins burrowing in holdfasts can cause significant losses of adult kelp plants.

Life history data

An intensive sampling program, designed to determine the distributions, abundance, population size structure, patterns of recruitment, and reproductive patterns of red and purple urchins is being carried out at Point Loma by Dr. Paul Dayton's group. We began to collect similar data last year from the northern Channel Islands and from the mainland near UCSB in order to complement Dr. Dayton's work and to enable us to compare the life history strategies of two potentially competing species.

Distribution patterns of adult and juvenile red and purple urchins were mentioned in the previous section. We obtained the following additional data regarding recruitment patterns of red and purple urchins: Recruitment of both species seems to be greatest during the summer and fall. *S. purpuratus* recruitment is greater than *S. franciscanus* recruitment in all habitats and at all seasons sampled so far. Purple urchin recruitment is significantly correlated with adult density, whereas red urchin recruitment is not. This happens even though almost all red urchin juveniles are found beneath adult red urchins, but purple urchin recruits are found in areas containing small cobble away from adults as well as beneath adults.

The reproductive periodicities of red and purple urchins were studied by monthly sampling of the gonad indices of urchins from the northern Channel Islands and from sites near UCSB. Preliminary results show significant decreases in gonad indices of red urchins between January and February of 1975, indicating that spawning has probably occurred.

Conclusion

In summary, our results of the past year show that red urchins are better space competitors than purple urchins. We have initiated red urchin removal experiments which will conclusively support or repudiate the hypothesis that removal of red urchins will lead to increases in the abundance of purple urchins. We have also begun experiments to evaluate the relative effects of purple and red urchin grazing on the kelp bed community. Our program for gathering life history data for both urchin species will enable us to suggest reasonable fisheries management practices to maximize the yield of sea urchins while minimizing the disturbance which such a fishery may cause to the kelp bed community.

Antioxidants for Marine Lipids

Davis
R/ST-1

H. S. Olcott

This is a final report of a study designed to provide new and better antioxidants which will be needed to prevent oxidation of the highly unsaturated lipids in marine food products.

The lipids of marine food products are unusually highly unsaturated and thus extraordinarily susceptible to oxidation, which leads to off-flavors and inedibility. Treatment with antioxidants is one method of extending the shelf life of such products. A few antioxidants are well known, approved, and widely used.

Formation of nitroxide free radicals

Our previous studies had led us to the concept that nitroxide free radicals were effective antioxidants and that compounds containing amino groups were oxidized to nitroxides in the oxidizing fat. Amino acids occur naturally in foods, both free and combined in proteins. Some of them are known to have antioxidant activity. This suggested to us that they might form nitroxide free radicals by mild oxidation. Our first Sea Grant trainee (T. C. Tom) was able to isolate and identify "proline nitroxide", which substantiated the hypothesis. Proline nitroxide was a better antioxidant than proline itself but it was relatively insoluble in oils; attempts to make oil-soluble derivatives were not successful. We next studied two other amino acids known to have antioxidant activity—histidine and tryptophane. Both give positive signals by electron-paramagnetic resonance methods. However, it was subsequently shown by another trainee (P. A. Murphy) that the signals were the result of oxidation to a free radical, not of the amino acids, but of the buffer that had been used to stabilize the pH. This was a new observation and has been published but did not help in the identification and use of antioxidants. We believe that the nitroxides of histidine, tryptophane and hydroxyproline can be made and characterized, but the problem was dropped.

The same theory suggested that the free radical nitroxide of ethoxyquin might account for its excellent antioxidant properties. Mr. James Lin, Research Associate supported by Sea Grant, synthesized and isolated this compound and showed that it was the active intermediate in the ethoxyquin antioxidant reaction. Since ethoxyquin has also been claimed to have other biological actions such as being anticarcinogenic and increasing the lifespan of experimental animals, this observation has far-reaching implications.

The detailed observations leading to these results are outlined in three theses and in subsequent publications. The work is being continued at present but without support and at a much reduced level.

Publications

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Cooperating Organizations

Hoffman-La Roche, Nutley, New Jersey
The Monsanto Company, St. Louis, Missouri
Van Camp Seafood Company, San Pedro, California

Studies of Fish Muscle Proteins and Fresh and Frozen Seafood Technology

W. D. Brown

It has now been found that the undesirable brown surface discoloration of precooked frozen tuna can be significantly reduced by vacuum-packing in a water-impermeable film.

As previously reported, a problem occurs when precooked and cleaned skipjack tuna loins are frozen, held in frozen storage for a few weeks, and subsequently thawed and canned. The problem manifests itself as a severe surface discoloration (brown areas). Our findings have shown that the discoloration results from at least two reactions—one involving lipid oxidation products and the other nonenzymatic browning in which the sugar ribose is released from tissue nucleotides during frozen storage. An important recent finding is that desiccation during the freezing process following the precooking tends to increase markedly the surface browning. The reasons are not completely clear, but may involve release of surface lipids with a concomitant increase in lipid oxidation. We have previously reported that coating the fish with lard prior to freezing inhibits the browning and presumed this was due to its acting as an oxygen barrier. This may well be a major cause, but it now appears that prevention of desiccation by the lard layer also plays a part.

We have tried, with some degree of success, a variety of glazing materials to be applied to the fish loins prior to freezing. However, the most promising finding was that vacuum packing the loins in a water-impermeable film significantly reduces the browning problem. Thus, trials have been carried out in which fish were precooked, and cleaned and the resulting loins were vacuum-packed in Cryovac films, then frozen. After being held in frozen storage for six weeks, the loins were removed, steamed and compared to controls similarly treated but not vacuum-packed. There was significant improvement in the film-packed loins. Subsequently, this procedure has been tried on a pilot scale in a commercial tuna cannery. The initial study proved successful, with the film-packed tuna being appreciably better than the controls. A second pilot scale study is under way.

Lipids of skipjack tuna

The finding that lipid oxidation was in part responsible for the browning problem led to a literature search in an effort to find a detailed description of the lipids of skipjack tuna. Such information was not found; a study has, therefore, been initiated to characterize these lipids. It is anticipated that the distribution of fatty acids in these lipids will resemble patterns known for other species of tuna, but it is of importance to document this.

Ribose analyses

The observation that the sugar ribose is also a factor in the tuna browning led us to an evaluation of existing methods for the analysis of this sugar. None was found to be particularly suitable for the determination of ribose in fish samples, without considerable modification. A number of modifications to existing techniques have therefore been made to adapt them for tuna muscle. A manuscript describing procedures in detail is in preparation.

Yellowfin tuna myoglobin

We are continuing our study of the fine details of structure of this tuna myoglobin, specifically the determination of the sequence of amino acids in it. This is tedious work; however, the recent acquisition by the Davis campus of a protein sequenator should make possible an acceleration of this study. A paper describing in detail the composition of the tryptic peptides of this myoglobin is in preparation. This part of the work describes the sequence of somewhat more than half the amino acid residues in this protein.

A paper describing other features of yellowfin tuna myoglobin, including isoelectric point, reactivity of certain amino acid side chains, some spectral properties, sedimentation coefficient, molecular weight and relative stability to denaturation, has been submitted for publication.

Oxidation and reduction of fish myoglobin

Work in this area is continuing inasmuch as it is highly beneficial to quality (i.e. desirable surface color) to keep myoglobin in the reduced state. Particular emphasis is currently being placed on the identification

and purification of enzyme(s) involved in myoglobin reduction reactions. These studies include evaluation of the contribution of nonenzymatic systems to the reaction and a comparative study in which several species of fish are included.

Controlled atmosphere storage

This is a very promising area in which work has just been initiated. It is being done in cooperation with TransFresh Corporation, a company that provides controlled atmosphere storage mixtures (primarily carbon dioxide and nitrogen) for the ship, rail, and truck transport of a number of vegetables. Preliminary studies in their laboratories and in the field have shown considerable promise for the use of similar gas mixtures in the storage of meat and fish products. To date only limited work has been done with fish (red snapper and rex sole). However, our results indicate that samples stored in controlled atmospheres remained in good condition for a period considerably beyond that of the controls. We will be investigating the fate of carbon monoxide (included in some mixtures and which markedly improves surface color) to determine, e.g., the extent to which it is lost during cooking. We are also investigating the mechanism by which these gases inhibit microbial growth. Preliminary arrangements have been made to carry out pilot scale studies with fish of known good quality in cooperation with commercial fish processors and distributors.

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Cooperating Organizations

California Seafood Institute Research Committee, Sacramento, California
Silliker Laboratories, Vernon, California
TransFresh Corporation, Salinas, California
Tuna Research Foundation, Terminal Island, California

Natural Fermentation of Marine Products

E. V. Crisan and M. W. Miller

Fermentation, a method commonly employed for the preservation of foods, was studied in detail in this project as a potential means of expanding the use of marine resources. More particularly, it was sought to develop selective fermentation procedures for the conversion of fishery processing wastes into products of commercial value, and at the same time reduce the undesirable environmental impact of such wastes.

Foods of marine origin constitute a major source of nutrition in many oriental countries. Fermentation is one method commonly used to preserve sea foods and other food products; it also provides a means of expanding the use of marine resources. During fermentation, critical changes occur in the components of the raw materials which serve to increase and/or improve their nutritional value, digestibility and/or palatability. Since these raw materials must undergo various types of enzymatic conversions or degradations during fermentation, the microorganisms involved in the process must be capable of elaborating the proper enzymes in sufficient quantities to accomplish the desired changes. It can be expected, therefore, that these same organisms can ferment other products of marine origin in a similar manner to produce potentially valuable nutritional products.

The objectives of this project were to determine (i) which types of changes occur during the fermentation of sea foods, (ii) which microorganisms within the general microflora of the product are responsible for these changes, and (iii) the feasibility of using these microorganisms to develop specific selective fermentation procedures for converting fishery processing wastes into products of potential nutrition and/or commercial value. Such fermentation procedures, if available, would provide an alternative to the methods of waste disposal currently in use and permit the reutilization of waste products which now have an undesirable environmental impact.

Fermented sea foods and their microflora

To achieve these objectives, it was first necessary to study several fermented sea food products to determine the types of microorganisms involved and the relative enzymatic capabilities of these organisms. A variety of fermented sea foods were obtained from commercial sources within the United States and abroad. These samples represented three general types of product: (i) those prepared from various whole marine organisms or parts therefrom, fermented to produce liquid-solid mixtures, (ii) those prepared from whole fish or shellfish and fermented completely to produce a syrupy liquid having a high suspended solids content (sauces), and (iii) those fermented similarly but under low moisture conditions to produce a semi-dry product (pastes). In all cases, the raw materials are mixed with salt to produce a brine of varying concentration depending on the type of final product desired. The raw materials undergo a slow fermentation process requiring from one to six months. During fermentation, various additional treatments may be completed such as the addition of water or salt (if necessary), mixing and maceration.

Upon completion of fermentation, the raw materials have undergone extensive proteolysis during which the fish protein has been converted into soluble amino acids and various other organic and inorganic nitrogen compounds. The texture of the raw material has also changed in consistency, with various degrees of liquefaction occurring depending upon the type of finished product desired. Concurrently with the changes in protein and texture, other components are acted upon; a significant decrease in the lipid content occurs, and various flavor compounds are developed. The latter is a result of both the destruction of undesirable flavor compounds naturally present in the raw material and the formation of new compounds characteristic of the fermented food produced. These various changes have been attributed to the action of enzymes present in the raw material and/or elaborated by the microorganisms active during fermentation. These microorganisms originate from several sources which may include the microflora of the entrails of the raw material, the surface microflora present on the raw material when harvested, the organisms present on the boat or equipment used for harvesting, and those present as contaminants at the point of fermentation.

Fifteen fermented sea foods were analyzed to isolate and identify their microflora. The

samples consisted of 10 different types of products derived from raw materials consisting of whole or parts of marine organisms, three samples of fish sauces, one of shrimp sauce, and one of shrimp paste. Where possible, multiple samples of a specific type of fermented sea food were analyzed, representing the food at various stages of fermentation. This information was used to provide a better understanding of the sequential changes occurring in the microflora during the fermentation process.

The various genera and species of microorganisms isolated from these samples are listed in Tables 1 and 2. Members of the spore-forming genus *Bacillus* were common to all products and were represented by a number of species and sub-strains. A single species, *Pediococcus halophilus*, occurred in many products and may have been instrumental in flavor development since members of this genus function in that capacity in other fermented foods. A variety of other genera and species were encountered in one or more products and may have contributed to the specific characteristics of those products.

An extensive study of belachan (blachan), a shrimp paste used extensively in Malaysia, was conducted. In other parts of Southeast Asia this paste is also consumed under such names as kapi, ngapi, trasi, bagoong, or prahoc; it is prepared from a variety of Mysid-type shrimp, particularly *Acetes* species. The fermentation involves a proteolytic and chitinolytic digestion of the raw shrimp by both endogenous and microbial enzymes. The process is carried out in the

TABLE 1. Microflora of 10 Fermented Sea Foods

Product	Raw Material	Microbial Species
Alaskan pollack, intestines	*Theragra chalcogramma*	*Bacillus cereus, B. firmus, B. licheniformis, B. pumilis, B. subtilis*
Alaskan pollack, roe	*T. chalcogramma*	*Bacillus subtilis, Micrococcus colpogenes, M. flavus, M. luteus, Debaryomyces hansenii, Hansenula anomala*
Anchovy, whole animals	*Engraulis japonicus*	*Bacillus cereus, B. megaterium, B. pumilis, Clostridium setiense, Pediococcus halophilus, Serratia marcescens*
Clam, muscle	*Cardium* spp., *Meretrix* spp., *Venus* spp.	*Bacillus megaterium, Micrococcus colpogenes, Pediococcus halophilus, Pseudomonas ovalis*
Cuttlefish, muscle	*Sepia* spp.	*Bacillus cereus, B. pumilis, Micrococcus colpogenes*
Fish, roe	Unidentified	*Bacillus firmus, B. subtilis, Micrococcus luteus, Pediococcus halophilus, Debaryomyces hansenii*
Oyster, muscle	*Ostrea* spp.	*Bacillus megaterium, B. subtilis, B. subtilis var. atterrimus, Pediococcus halophilus*
Sea arrow, muscle and organs	*Ommastrephes solani pacificus*	*Bacillus cereus*
Sea urchin, gonads	*Heliocidaris crassispina*	*Bacillus cereus var. mycoides, B. licheniformis*
Shrimp, whole animals	*Palaemon* spp., *Penaeus* spp.	*Bacillus cereus var. mycoides, B. pumilis, Pediococcus halophilus*

TABLE 2. Microflora of Five Fermented Fish Sauces and Pastes

Product	Raw Material	Microbial Species
Fish sauce (Nampla)	*Stolephorus* spp., *Sardinella* spp.	*Bacillus cereus, B. circulans, B. licheniformis, B. megaterium, B. pumilus, B. subtilis*
Fish sauce (Ounago)	Unidentified	*Bacillus cereus, B. megaterium, Aspergillus* sp., *Cladosporium herbarum*
Fish sauce (Patis)	*Stolephorus* spp., *Sardinella* spp., *Legnathus* spp., *Decapterus macrosoma*	*Achromobacter thalassius, Bacillus coagulans, B. licheniformis, B. pumilus, Micrococcus colpogenes, M. varians, Candida clausenii*
Shrimp sauce (Koami)	*Mysis* spp.	*Bacillus cereus, B. megaterium, B. sphaericus, Penicillium notatum*
Shrimp paste (Belachan)	*Acetes* spp., Mysid varieties	*Bacillus brevis, B. cereus, B. circulans, B.coagulans, B. firmus, B. licheniformis, B. megaterium, B. pantothenicus, Brevibacterium* sp., *Clostridium bifermentens, C. haemolyticum, C. kluyveri, C. pasteurianum, Flavobacterium* sp., *Lactobacillus leichmanii, Micrococcus* sp., *Pediococcus halophilus, Sarcina* sp., *Staphylococcus aureus, S. epidermidis*

presence of high concentrations of salt under anaerobic conditions.

A microbiological analysis of 18 samples of belachan, taken from various stages of fermentation, was conducted to characterize the microflora. The samples were obtained from commercial producers in Southeast Asia and, in the case of some completely fermented samples, from commercial outlets in the United States. During the initial stages of fermentation, a microaerophilic homofermentative, salt-tolerant species of *Pediococcus*, *P. halophilus*, was the predominant microorganism and appeared to contribute to the desired changes in texture and flavor. As the fermentation progressed to completion, the microflora became composed almost exclusively of seven aerobic, halophilic, spore-forming species of the genus *Bacillus*. As the shrimp paste matured, however, increasing numbers of *Micrococcus* sp. and *Staphylococcus* sp. were detected and four samples contained potentially pathogenic strains of coagulase-positive *Staphylococcus aureus*.

Since the belachan samples contained 13-18 per cent salt to prevent spoilage, the species and strains isolated from the samples exhibited a high degree of salt tolerance (halophilism). Even though *Pediococcus* was predominant during the early stages of fermentation, a lowered pH, which is characteristic of many fermentations involving this genus, was not noted in the belachan fermentation. The prevention of spoilage appeared to be due only to the high salt content.

Fermentation studies

It was hypothesized that microorganisms responsible for the desirable fermentation of sea foods could be used as tools to modify the composition of other fishery products and thus produce acceptable food or feed supplements. By selecting microorganisms having specific enzymatic capabilities, fermentation processes may be designed to degrade undesirable components such as lipids of off-flavor compounds without affecting the composition of desirable components such as proteins.

Protein and lipid are the major components of marine products which have actual or potential food value. Fishery wastes contain large amounts of unrecovered protein and lipid which represent a significant loss to the world food resource and, in fact, create serious problems of environmental pollution during waste disposal. In addition to these major food components, waste from crab, shrimp, and lobster fisheries contain large amounts of chitin, a nitrogen-containing compound of limited nutritional value.

Commercial fish meal was chosen as an "ideal" experimental substrate due to its high protein content, its availability in quantities which would ensure a continuous supply of a relatively homogeneous product, and its high content of lipid and trimethylamine (TMA). The high lipid content is undesirable in a food product, because fish lipids are easily oxidized to produce rancidity, off-flavors and odors. The TMA is also undesirable on account of its involvement in the development of "fishy" flavors and odors.

Preliminary fermentations were conducted using various concentrations of fish meal together with a limited amount of other nutrients. Cultures of several bacteria and fungi were used as fermentative organisms because of their known lipolytic activity. For comparison, fermentations were also conducted with *Candida lipolytica*, a strongly lipolytic yeast used for similar fermentations of fishery products by other workers. The initial studies were designed to identify the basic parameters of fermentation and determine the overall type of enzymatic activities which take place during the fermentation process. Analyses were made after various time intervals to determine the changes occurring in the lipid, trimethylamine, protein, and amino acid composition of the product.

Among the organisms tested, filamentous fungi appeared to be the most promising fermentative agents for reducing the lipid and TMA content of the product. The relative capabilities of each type of organism studied are compared in Table 3.

TABLE 3. Relative Changes in the Lipid and Trimethylamine (TMA) Content of Fish Meal after Fermentation

	Lipid %	TMA %
Fish meal control	100	100
Bacteria	25-40	164
Yeasts	26	80
Filamentous fungi	16	52

The crude protein content (arrived at by determining the nitrogen content and multiplying this by a factor of 6.25) of the fermented product appeared to increase. In actuality, however, this was only an apparent increase since the amount of protein was determined using the standard method of analysis which assumes that all of the nitrogen content is in the form of protein. A

discrepancy arises, however, when a portion of this protein nitrogen is converted to nonprotein nitrogen. In fermentations with *C. lipolytica*, for example, a 5 per cent increase in the crude protein content (N x 6.25) was accompanied by a 54 per cent loss in amino acids, as determined by direct amino acid analysis. The loss in true protein was not unexpected, however, since the culture substrate was not supplied with any source of nitrogen other than that present in the fish meal. Consequently, the fermentative microorganisms must utilize a portion of the fish meal nitrogen to supply their own metabolic needs. This reduction in protein can be offset or prevented by providing other more readily utilizable sources of nitrogen, e.g. urea, in the fermentation substrate.

The fish meal samples that were fermented with yeasts and filamentous fungi, differed considerably from the unfermented fish meal. After fermentation the dried solids appeared lighter in color, finer in texture, and the undesirable "fishy" odor was replaced by a pleasant "earthy" odor.

One problem that was encountered during the initial fermentation studies was the sparsity of cultures having known activity against specific substrates. This was compounded by the fact that, even where organisms were known to be lipolytic or proteolytic, their activities had been determined against substrates of terrestrial origin, e.g. vegetable oils and casein. Since the enzymes of many microorganisms exhibit extreme substrate specificity, those that are active against lipids and proteins of terrestrial origin may not be, and in many cases were not, active against lipids and proteins of marine origin. To provide a ready supply of fermentative microorganisms having diverse enzymatic capabilities against substrates of marine origin, it was necessary to develop specific assay procedures using marine substrates and to assay numerous microbial cultures to determine their enzymatic activity against these substrates.

A lipolytic assay medium containing a menhaden oil-nile blue dye complex in a nutrient agar base was developed. Since the dye complex was not toxic to the microorganisms, the medium could be used for both isolation and assay, simultaneously, thereby eliminating a time-consuming two-step procedure of isolating all of the organisms present in a sample followed by the assay of each organism to determine its activity. Organisms elaborating lipases active against the menhaden oil were easily detected since they were surrounded by a blue zone of free dye against the red background of the fish oil-dye complex contained in the medium.

Similarly, an isolation/assay medium was developed to detect proteolytic microorganisms using a proteinaceous extract of fresh cod fish incorporated into a nutrient agar base. The suspended extract caused the medium to become opaque, and proteolytic organisms capable of digesting the cod fish protein were detected by the clear zones which surrounded them against the opaque background.

Lastly, a nutrient medium containing a fine, colloidal suspension of chitin was used to detect chitinolytic activity. Chitinolytic organisms were detected by the clear zones which surrounded them after they digested the opaque suspension of chitin.

Of the 228 bacterial species and strains tested for lipolytic, proteolytic, and chitinolytic activity, some showed specific activity against only one or two of the marine substrates or, in a few cases, all three substrates. Fungi (67 isolates), on the other hand, only exhibited lipolytic and/or proteolytic activities but none was chitinolytic (Table 4).

TABLE 4. Enzymatic Activities of Microbial Isolates against Lipid, Protein, and Chitin of Marine Origin

	Bacteria		Yeasts and Filamentous Fungi	
	Number	%	Number	%
Lipolytic only	11	4.8	12	17.9
Proteolytic only	133	58.3	5	7.5
Chitinolytic only	5	2.2	0	0.
Lipolytic + proteolytic	9	3.9	12	17.9
Lipolytic + chitinolytic	1	0.5	0	0.
Proteolytic + chitinolytic	13	5.7	0	0.
All three activities	3	1.3	0	0.
No activity	53	23.2	38	56.7

Using the enzymatic assay information obtained above, fermentations were carried out in media containing 5, 10, 15, and 20 per cent fish meal. Five bacterial strains were used, exhibiting various degrees of lipolytic and proteolytic activity against marine and nonmarine substrates. After fermentation for 70 hr, fermented samples and uninoculated controls were harvested and analyzed for the crude protein content (N x 6.25) of the solids and supernatant solution.

The fish meal contained 15-20 per cent soluble matter which dissolved into the supernatant solution during incubation. This decreased the amount of nitrogen in the insoluble solids and accounted for a large proportion of the nonprotein nitrogen which normally is not distinguished from crude protein during standard analysis. The degree

of solubilization occurring in uninoculated controls was affected by the length of the incubation period and, more significantly, by the concentration of fish meal in the fermentation medium. As the concentration of substrate was increased, the relative amount of material solubilized decreased; this occurred in both control and inoculated cultures. In the latter case, the data indicated that a sufficient amount of soluble nutrients (including nonprotein nitrogen) was available to support growth, thereby reducing the requirement for the organism to rely on the digestion of protein as a source of nitrogen. The observation was confirmed by the fact that even strongly proteolytic strains produced fermented solids containing 40 per cent protein. This is of significance as the analyses more closely approximate true protein since the organisms utilized nonprotein nitrogen for their metabolism.

Fermentations were also conducted using fish meal, and fish meal supplemented with a nonprotein nitrogen source (0.5 per cent urea). Microorganisms lacking proteolytic capability produced 10-20 per cent more crude protein in solids from fermentations supplemented with urea. Proteolytic cultures, on the other hand, showed a slight increase in the protein content of the fermented solids and, in the case of one organism, exhibited better protein production in the absence of the urea supplement.

Two yeast cultures showed opposite results, *Geotrichum candidum* produced slightly more protein in solids from fermentations without urea, while *Candida lipolytica* produced solids containing 30 per cent more protein when the fish meal was supplemented. This confirmed our earlier study indicating that *C. lipolytica* would not utilize protein as a nitrogen source if the medium is supplemented with a more readily utilizable source of nitrogen.

Potential nutritional value of broth

The crude protein content of the supernatant fermented medium was also considered as a potential source of nutritional compounds. In fermentations containing 5 or 10 per cent fish meal, supplemented or unsupplemented, the supernatant medium contained 10-70 per cent of the total protein. When 15 or 20 per cent fish meal was fermented, however, the protein content of the supernatant dropped to an average of less than 10 per cent of the total protein. Since this crude protein included some nonprotein nitrogen, the practicality of utilizing the fermentation broth from such fermentations was doubtful. If, however, further analyses establish that other compounds of nutritional value such as vitamins are present in the fermentation broth, the broth may become a valuable by-product.

The study of chitinolysis has continued with the development of suitable assay and fermentation procedures. One recurring problem with the fermentations has been the relatively slowness of the process. Although several actively chitinolytic organisms have been isolated and are being studied, the rates at which these organisms degrade crude chitin (shrimp and crab shells) are too slow for the development of a practical fermentation. Studies which are to continue beyond the termination of this project will study the parameters of the chitinolytic fermentation to provide the optimal conditions of fermentation. Recently, additional chitinolytic microorganisms have been isolated from chitinous materials obtained from a Gulf Coast processing facility. The material had undergone natural degradation prior to processing. Several fungi, actinomycetes, and bacteria isolated from this material have been assayed and found to exhibit considerably higher chitinolytic activity than the organisms presently available. Studies to determine their rate of chitinolysis are in progress.

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Cooperating Organizations

Food Technology Research and Development Centre, Division of Food Technology, Ministry of Agriculture and Land, Sungei Besi, Selangor, Malaysia

Hueneme Fish and Bait Processors, Port Hueneme, California

Korean Institute of Science and Technology, Seoul, Korea

Marine Commodities International, Inc., Brownsville, Texas

Point St. George Fisheries, Santa Rosa, California

Marine Resource Management Intern Research Program

San Diego
R/ME-2

James J. Sullivan

Under the experimental Marine Resource Management Intern Research Program, selected advanced graduate students in the social sciences were given the opportunity to acquaint themselves with those marine resource problems that are basic to policy making. The students' contributions should prove helpful to policy makers and at the same time broaden their own perspectives.

Optimal Resource Management under Conditions of Uncertainty: the Case of an Ocean Fishery

Tracy Lewis

Rational management and utilization of the ocean fisheries become more critical as the demand for marine resources increases. This study aims to determine the optimal management program for the tuna fishery, considering different environmental and economic conditions and assuming the objective is to maximize the net economic value from the resource.

The problem of allocating a renewable or non-renewable natural resource over time to maximize net economic returns is described in general terms in the form of a finite state and action Markovian decision process. The basic model we introduce allows for the important effects of environmental variation on the natural growth and depletion of the resource and the effect of random changes in socio-economic conditions on market prices and the costs of extraction. This model is used to analyze the Eastern Pacific yellowfin tuna fishery, and the following results were obtained.

Impact of uncertainty

The effect of uncertainty regarding prices, and growth and depletion rates on optimal allocation strategies are analyzed for situations where society is averse or indifferent to variations in the returns from the fishery. The impact of uncertainty on consumption programs is directly related to the amount of variation in fishery rents determined by the size of the expected catch and the degree of fluctuation in the price and depletion rates. The variability of rents increases as the population increases, since the expected catch is typically larger, the larger the population. Key changes in optimal effort allocations occurring in a stochastic environment for different populations are of the following form:

For the risk neutral social planner, the allocation of effort and the resultant expected catch tend to remain constant or decrease as the price and growth and depletion rates become more uncertain. The largest changes in effort take place at the upper end of the populations to take advantage of the small fluctuations in rents, and decreases effort for larger populations to avoid greater risk in returns.

The qualitative nature of our results are the same for all different forms of the frequency function analyzed. The most important element of the parameter distributions influencing allocation strategies is the range over which the variables are allowed to fluctuate. Optimal effort allocations corresponding to variable depletion rate cases are affected only slightly by allowing simultaneous variation in the natural growth rate.

The policy implications evolving from this analysis are: (1) Using the discount rate to capture risk is inappropriate, since risk is not a simple compounding function of time and no overall adjustment in the interest rate is suitable, and (2) solutions to deterministic problems serve as excellent approximations for stochastic solutions in some class cases. However, for the other classes a probabilistic treatment of the resource allocation problem is needed, since deterministic consumption rules are poor substitutes for optimal stochastic strategies.

The Cultural Systems of the Tuna Seinermen of San Diego, California

Michael Kenneth Orbach

This thesis is about the men who sail with the high-seas tuna fleet out of San Diego, California. It describes the ways in which they find and catch the tuna, and the interactions with their shipboard environment and with the people in the communities in which they live when ashore.

The high-seas tuna fleet contains about 135 boats. They average 220 feet in length and cost from 2.5 to 5 million dollars to build. They catch the tuna exclusively by

the purse-seine method. Seventy per cent of the fleet has been launched since 1970, and all of the boats are modern and well equipped. The fleet as a whole is efficient, well financed, well managed, and forms the base of a thriving industry in San Diego.

Ethnic make-up of fishermen

There are between 1500 and 2000 fishermen in the fleet, and they are predominantly Portuguese, Italian, Mexican, and Central and South American. The Portuguese and Italians are the major driving force behind the industry. Many of them live in two relatively bounded spatial communities, one Italian and the other Portuguese, in the San Diego area. Each community has churches, stores, and various facilities where their native language is spoken and their particular cultural needs are met. Men of these two ethnic groups started the industry in San Diego, and it is thanks to their efforts that it has flourished. They own or control the major portions of both the tuna boats themselves and the infrastructural elements of the industry ashore.

The fishing has traditionally taken place from the northern border of Chile in South America to the coast of Baja California in North America, and anywhere from 2 to 2000 miles offshore. The average length of a fishing trip is 60 days, and the men are at sea for from 8 to 11 months of the year. The average crew is 15.

There are three general themes which run through the study. First, economic systems are always deeply affected by the social attitudes, understanding, and behavior of the people involved in them. Secondly, a system that requires a small group of men to be at sea in a confined, isolated, dangerous and uncertain environment for long periods of time will tend to produce specific social mechanisms and mental attitudes to deal with the effects of that system. Thirdly, the imprint which that system leaves on the men who participate in it will affect the nature of their attitudes towards and interactions with the various sets of people with whom they must deal when ashore—their families, friends, and the larger community.

Understanding the cultural framework

The method of the study was participant observation. The researcher lived in the Portuguese community for two years, and made two trips to sea as a deckhand aboard two different boats. A total of five months was spent at sea, it being known aboard that material was being collected for the research. The data from the researcher's observations were checked through conversations and interviews with crewmen from other boats in the fleet and various people in other parts of the industry.

The thesis attempts to describe the fishermen's cultural understanding, which enables them to deal systematically with situations they encounter in making a living. Although various theoretical perspectives concerning the three themes set out above are explored, the main thrust of the work is to enable the reader to understand the relevant parameters of the tuna seining occupation from the point of view of the men who go to sea onboard the tuna boats.

Publications

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Cooperating Organizations

National Marine Fisheries Service, La Jolla, California
The San Diego Tuna Fishery

Determination of Appropriate Levels of License Fees and Extraction Fees for Vessels Fishing for Yellowfin Tuna in the Eastern Tropical Pacific

San Diego
R/ME-3

Virginia G. Flagg

This study identifies several problems in the eastern tropical Pacific tuna fishery stemming primarily from economic factors. Since no one owns the ocean, economic exploitation of the tuna by many fishermen from several countries has given rise to conflicting pressures.

An important economic problem in the tuna fishery is the presence of excess capacity. It is estimated that there are about twice as many vessels in the fishery now as would be needed to harvest the maximum sustainable yield of yellowfin plus a normal harvest of skipjack. If there were only half as many fishing vessels, both society and the individual fisherman would benefit. The latter would benefit by being allowed to catch more yellowfin, and his costs could be kept lower by spreading his operations evenly over the year. Society would benefit in saving scarce economic resources. Though the same amount of fish would be caught, there would be smaller expenditure of fuel and other trip necessities. In the long run, less steel and other resources would be utilized in building and maintaining a smaller fleet, and these resources could be used by society in other ways.

Under the auspices of Sea Grant, owners and operators of United States and foreign tuna vessels were interviewed to obtain cost data. Preliminary analysis of these data indicates that if the fleet were reduced by half, revenue to each vessel would increase (through greater fishing possibilities) sufficiently to permit a fee in excess of $100 to be collected on each short ton of yellowfin landed, without jeopardizing the profitability of the boat. Assuming a conservative estimate of the maximum sustainable yield of yellowfin to be 150,000 short tons, $15 million could be collected annually.

This amount of money could benefit the fishermen and society in several ways. It could be used to help the fishermen find fish; it could be used in an insurance fund; and most importantly, it could be used in financing an international enforcement and licensing system. An annual quota is placed upon the catching of yellowfin in a regulatory area by the Inter-American Tropical Tuna Commission, of which the United States is a member. American fishermen complain that during the closed season, when it is illegal to catch yellowfin, fishermen from other countries violate the regulations with impunity. Enforcement must be on an international scale for the sake of equity.

Other countries could benefit from the collection of a fee for the privilege of fishing. The Central and South American countries, off whose shores the tuna swim, claim they are entitled to a share of the proceeds derived from the harvesting of the resource. Though the Law of the Sea Conferences have not yet settled the matter, the concept of a 200-mile economic zone is becoming more widely accepted. If the coastal nations were permitted to derive revenue from the harvesting of tuna by other nations, in proportion to the amount of fish caught off their shores, a significant problem could be solved. At the present time there is uncertainty and ambiguity about where fishermen can safely fish, and this uncertainty leads to confrontations, as for example when a foreign nation seizes American boats suspected of fishing without license off that country's shores.

Concept of limited entry

Ideally, limited entry for tuna fishermen should be handled by an international agency on an impartial basis, permitting the most efficient fishermen of any nationality to win the privilege of fishing. Practically, however, it is unlikely that national rivalries would allow such an arrangement. It may be possible through bargaining to arrive at national quotas, and then the United States could limit its own fleet size by some means to achieve greater efficiency.

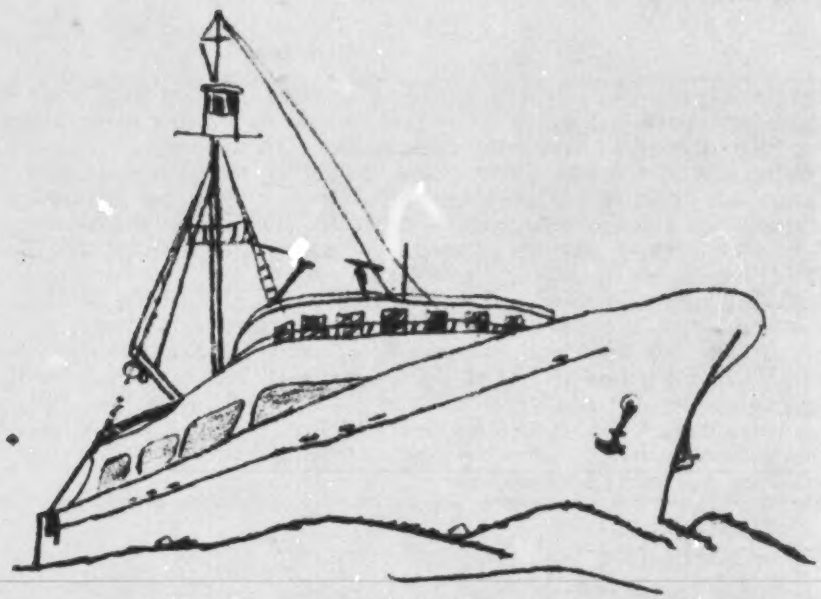
After examining several possible means of limiting entry into the fishery, it is concluded that the method of fisherman quotas, first proposed by Francis T. Christy, Jr., has considerable merit. Under this system, fishermen would be permitted to lease or buy the privilege of catching a certain percentage

of the maximum sustainable yield. Such a limited entry system must be introduced very gradually so that those already in the fishery will not suffer.

Through this economic study of the tuna fishery, greater understanding has been gained of how rationalization of the industry would affect not only the profitability of the individual fisherman in the United States, but also the prospects of other countries as they make decisions regarding their participation in the fishery.

Cooperating Organizations

American Tunaboat Association, San Diego, California
Fishermen, fishing companies, canneries
Inter-American Tropical Tuna Commission, La Jolla, California
National Marine Fisheries Service, La Jolla, California
Western Fish Boat Owners Association, San Diego, California



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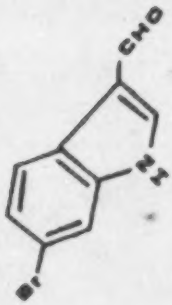
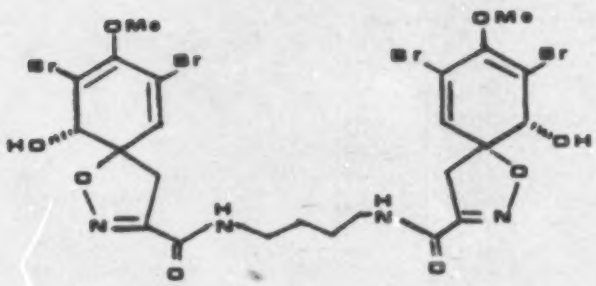
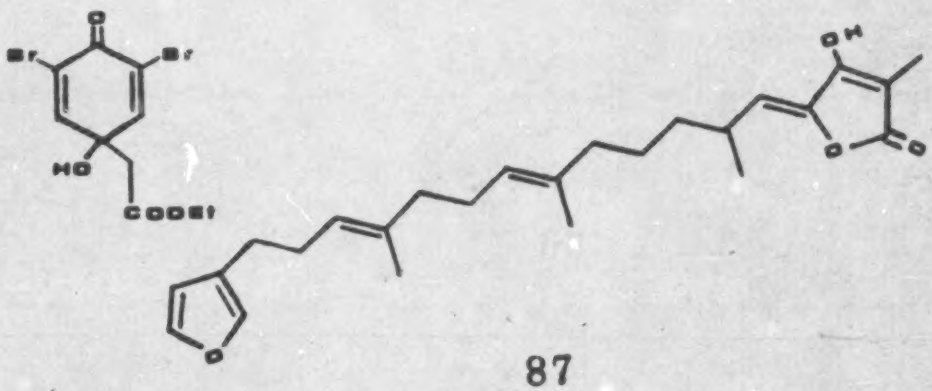




NEW MARINE PRODUCTS

Originally this research effort was directed primarily at obtaining new drugs from the sea, but now the program has been redirected to emphasize the search for other useful chemical products of marine derivation for industrial and agricultural use. A project at UC-Riverside was concerned with the utilization of algal derivatives as fungicides and insecticides; it met with some success and was concluded in 1974. In another project, Scripps investigators found that natural insect hormones and synthetics which mimic these natural compounds possess very powerful anti-barnacle activity, but more general antifouling effectiveness was lacking. If the spectrum of effectiveness of hormones could be broadened, the environmentally damaging necessity for utilizing antifouling paints containing heavy metals and other persistent toxicants would be eliminated. Another project at Scripps is directed toward development of algicides, substances for control of pathogens in aquaculture, and insecticides and herbicides for agricultural use. A third Scripps project addresses the problem of determining the levels of "natural background pollution" existing because of the synthesis of halogenated hydrocarbon compounds by many marine plants and animals. The presence of these naturally occurring compounds has undoubtedly resulted in incorrect determinations of levels of concentration of persistent man-made pollutants such as DDT.



Marine Natural Products Chemistry

San Diego
R/MP-4

D. J. Faulkner

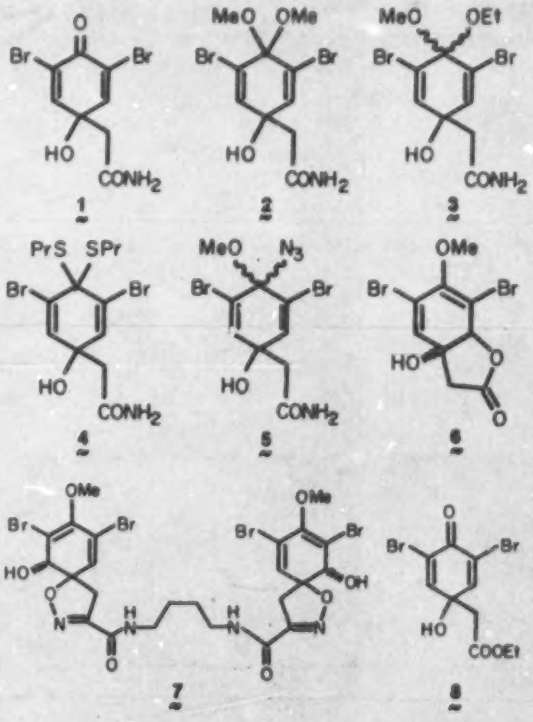
The *in vitro* antibiotic activity of several marine organisms is due to small molecular weight lipids, some of which have molecular structures which are unique to the marine environment. Insect hormones and their synthetic analogues may be used to inhibit settling of barnacles. The extracts of a marine alga gave simple substances which inhibit the growth of microorganisms pathogenic to crustaceans and fish.

During the four-year grant period, our research objectives have changed several times, mainly at the behest of the various Sea Grant review committees. Throughout the whole period, we have sought practical applications of the results of our basic research programs funded from federal and industrial sources. Our research began as a search for new pharmaceuticals, with the emphasis on antibiotics. Although we have identified new natural products with potential use as antibiotics at a faster rate than any other U.S. group engaged in marine natural products research, none of these compounds has been adopted for commercial development. We have also studied the use of marine natural products and synthetic insecticides as antifouling agents. We have demonstrated very powerful anti-barnacle activity of natural insect hormones and of synthetic mimics of these compounds, but we learned from field tests that we must find compounds having more general antifouling activity. Finally, we have tackled the problem of finding compounds with activity against marine bacteria pathogenic to commercial shellfish. One series of products shows some promise of success.

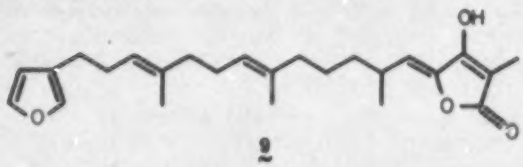
Potential pharmaceuticals from marine organisms

Our research on potential pharmaceuticals from marine organisms has been rewarding and at the same time frustrating. We have identified many new antibiotics, but most of these are either too unstable or too toxic for use by the pharmaceutical industry. Although the toxic compounds could be employed as antiseptic agents, they cannot compete with the synthetic materials in current use. Our studies have, however, led to the discovery of several new classes of chemical compounds and have provided an explanation for previous reports of *in vitro* antibiotic activity in many classes of marine organisms.

We have investigated several species of *Verongia* (sponge) and have found that the antibiotic activity of the sponge extracts, and therefore the constitution of the products, is more dependent on the method and solvent of extraction than on the species of sponge extracted. Extraction of *Verongia* species (several) with aqueous acetone gave the dienone 1, while extraction with methanol, ethanol, propane thiol and sodium azide in acetone gave the ketals 2 and 3, the thioketal 4 and the azide 5, respectively (as mixtures of geometrical isomers in 3 and 5). Whereas the dienone 1 is strongly antibiotic in an *in vitro* assay, the remaining products exhibit little or no activity. We also isolated the lactone 6 and aerothionin 7 from a *Verongia* collected in the Gulf of California. From *Tylodina fungina*, a mollusc which feeds exclusively on *Verongia*, we obtained a dienone 8, but we believe that this compound is a product of addition of the extraction solvent ethanol to the lactone 6. Further examination of these compounds has revealed that they are toxic to mice and therefore probably unsuitable for pharmaceutical use.



The antibiotic activity of *Ircinia variabilis* was located in a single compound, variabilin 9, which was isolated and identified by spectroscopic methods. Variabilin proved to be too unstable for practical use as an antibiotic. Although variabilin was shown to be active in a screen for anti-cancer drugs, the material decomposed before the test could be repeated.



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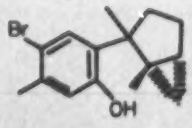
Most species of *Laurencia* (red alga) exhibit antibiotic activity when crude extracts are tested. In several species, such as *L. pacifica*, the activity has been shown to be due to laurinterol 10 and debromolaurinterol 11. We investigated the local alga *L. subopposita* and found that the major component, oppositol 12, was slightly active against *S. aureus*. Reinvestigation of this alga has revealed that oppositol 12 was inactive but that the activity was due to laurenol 13 and bromolaurenol 14, which are the major phenolic compounds in this alga. Bromolaurenol 14 is to be preferred over laurinterol 10 as an antibiotic, since it is stable to acid and base, whereas laurinterol 10 is inactivated by rearrangement to aplysin 15 under relatively mild conditions.



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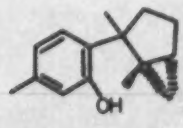

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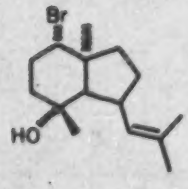

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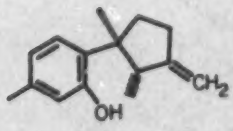

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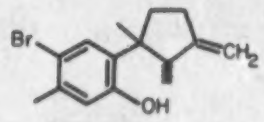

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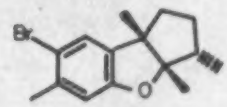

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Our research on the antibiotic activity of *Plocamium* species was a most interesting chemical study which led to the discovery that the activity was due to the decomposition of the compounds. Jon Mynderse, a Sea Grant trainee, has isolated and identified 11 new halogenated monoterpenes from *P. cartilagineum* and four cyclic halogenated monoterpenes from *P. violaceum*. These compounds undergo autocatalytic decomposition when impure to produce hydrochloric and hydrobromic acids, which result in an apparent antibiotic activity. Despite this disappointing result, there is a possibility that one of these compounds might be an effective agricultural chemical.

Control of barnacle metamorphosis

Barnacles are among the most serious of fouling organisms because they become firmly cemented to the substrate. One must therefore seek methods that will prevent attachment of the cyprid stage to a substrate. We found that insect hormones and their synthetic mimics can prevent settling of barnacles in laboratory experiments.

In normal development, the cyprid stage of a barnacle searches for a suitable substrate, settles, and metamorphoses into an adult. Cement production commences at the settling stage. The obvious parallels between the developmental biology of insects and crustaceans, including barnacles, led us to suspect that insect moulting hormones and their synthetic analogues, intended as insecticides, might cause modifications of the metamorphosis of crustaceans. Nonetheless, we were surprised to discover that ZR-512 (Zoecon Corporation) caused metamorphosis of the cyprid stage of the acorn barnacle, *Balanus galeatus*, to the adult form before settling had occurred. After precocious metamorphosis, the unattached adult was unable to feed by its normal filtering process and ultimately died.

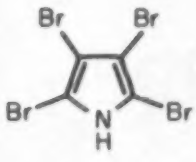
ZR-512 was incorporated into a paint and tested on plates in San Diego harbor. Initially, the plates remained free of barnacles, but they soon became covered with tube worms and other organisms, on which the barnacles duly settled. One must therefore conclude that the action of ZR-512

is too specific to allow its use as a general antifouling agent.

Control of pathogenic marine bacteria and fungi

When organisms are grown in monoculture, particularly under the high density conditions of mariculture, it becomes essential to control diseases, particularly those caused by water-borne organisms such as bacteria and fungi. During the last year of this grant, we maintained several marine bacteria, including *Vibrio anguillarum*, *Aeromonas hydrophila*, *Beneckea harveyi* and *Fusarium* species, in order to screen new natural products.

Since certain marine bacteria appeared to inhibit the growth of others by the production of antibiotics, we first investigated the antibiotics from *Chromobacter* species. The highly brominated metabolites tetrabromo pyrrole 16 and hexabromo-2, 2'-bipyrrole 17 and the phenol 18 are all highly active against marine bacteria. From a marine *Pseudomonas* species, we have isolated *p*-hydroxybenzaldehyde 19 and 6-bromoindole-2-carboxaldehyde 20, which are both weakly active against marine bacteria.



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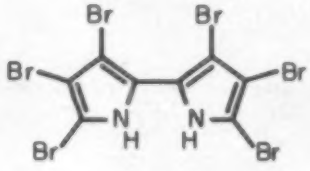

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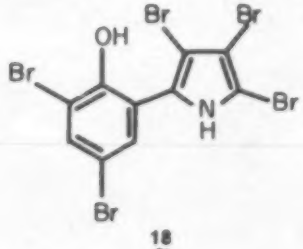

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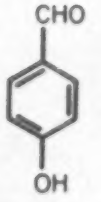

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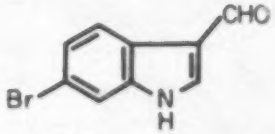

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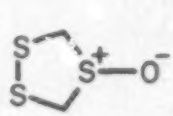
When it appeared that these compounds did not have the properties required for use in mariculture, we investigated the antibiotics from a marine alga, *Chondria californica*. The particular compounds which we have chosen to investigate are easily synthesized from dichloromethane, sulphur, and sodium sulphide, followed by periodate oxidation. We obtained a mixture of two compounds, the sulfoxide 21 and the thiosulfinate 22, which are under evaluation at present. They are active *in vitro* against *Vibrio anguillarum* and *Aeromonas hydrophila*. We believe that this mixture of compounds, cheap and simple to synthesize, may provide an acceptable treatment for pathogenic bacteria in mariculture.



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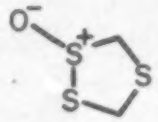

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Seaweed Products: Applications in Algae Control, Mariculture, and Agriculture

William H. Fenical

Chemical substances produced by marine organisms may provide new products for use in a variety of commercial applications. This project is designed to explore the application of these compounds in algae control, aquaculture disease problem control, and as insecticides and herbicides.

During the first year of this project, we began to investigate the applications of marine natural products in the following three areas:

- Antialgal active compounds for use as algae herbicides in antifouling;
- antibiotic agents for disease control in crustacean mariculture; and
- biodegradable herbicides and insecticides for agricultural applications.

To thoroughly explore these areas, industrial support has been secured from Kelco Company, San Diego, Stauffer Chemical Company, Mountain View, Searle Laboratories, Chicago, and the Environmental Research Laboratories, Tucson. These agencies are providing financial aid and/or are involved in testing services which are not feasible at our institution.

Antialgal compounds

In order to pursue the possible application of marine natural products toward controlling algae growth, a convenient bioassay has been developed and tested. Five species of unicellular algae that are important in the marine fouling process were selected. Twenty-milliliter cultures of each alga were illuminated at 18°C during a 10-day period and the cell count measured by a Coulter Counter. The variation between standard cultures and those which received additives reflects the degree of inhibition shown. In the past month, we have extracted over 100 samples of marine organisms and prepared 200 samples from products on hand. During the next year, these samples will be biotested.

Mariculture disease control

The disease problem in crustacean mariculture is by far the largest obstacle yet encountered. Since these marine bacterial infections are largely untreatable with existing antibiotics, we began to search for natural substances from the marine environment which show natural control. Working with the Environmental Research Laboratories (ERL) of the University of Arizona (currently culturing Penaed shrimp on pilot plant levels), we obtained cultures of pathogenic bacteria such as *Vibrio anguillarum*. *Vibrio* spp. are also important pathogens against lobster and salmon. To date, four seaweeds have been found whose extracts show antibacterial activity against *Vibrio*. These species are *Dictyopteris undulata, Asparagopsis taxiformis, Dasya pedicellata* and *Dictyopteris membranaceae*. Our approach was twofold. First, the ERL made special shrimp diet formulations including ca. 2% (w/w) of the dried seaweed material and conducted feeding experiments. Secondly, we attempted to isolate the pure antibiotics from each of these seaweeds. We have already been successful in isolating the active component from *Dasya* (see Figure). It was a surprise to find that the simple, readily available (ca. $9.00/kg commercially) compound, *p*-hydroxybenzaldehyde, was the major antibacterial component. We have furnished this pure antibiotic for pathological studies. These results are being published, in summary form, in *Phytochemistry*.

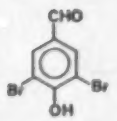
Antibacterial disc bioassay of the major metabolites from *Dasya pedicellata* var. Stanfordiana against *Vibrio anguillarum*

The active components from *Asparagopsis* are currently under thorough investigation. While these studies are not yet complete, the active components appear to be various isomers of polyhaloacetone and polyhalobutenone. These data have also been furnished to our industrial affiliate.

Biodegradable herbicides and insecticides

During the past year, we have provided a variety of compounds for broad-screen agricultural biotesting. This assay, conducted via our affiliation with Stauffer Chemical Company, has already confirmed that "active" substances are commonplace in marine organisms.

Two phenols, compounds I and II, from algae of the family *Rhodomelaceae* have shown activity in the herbicide screen against corn pests. In particular, I showed very encouraging control of mustard, a fact which suggests testing be completed with related substances.



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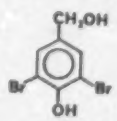
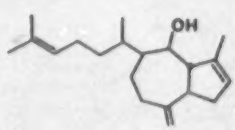


II

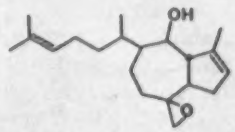
Herbicidal Activity, 8 lb/acre

	Control
Compound I	40% crabgrass
	95% mustard
	70% curly dock
Compound II	30% mustard

We recently isolated two diterpenes—pachydictyol A (compound III), and the related epoxide (compound IV)—from a *Dictyota* sp. Compound III has shown growth inhibition against grasses in the pre-emergence bioassay. Compound IV is currently being evaluated.



III



IV

We are most encouraged by the results of our first year's research, particularly in the area of new herbicide and insecticide development. Our cooperation with agricultural chemical companies will be strengthened in the coming year.

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Cooperating Organizations

Environmental Research Laboratory, University of Arizona, Tucson, Arizona

G.D. Searle and Company, Chicago, Illinois

Stauffer Agricultural Chemical Company, Mountain View, California

Naturally Occurring Halogenated Compounds: An Assessment of Their Interference in Pesticide Pollution Analysis

San Diego
R/MP-8

William H. Fenical

Halogenated compounds produced by marine organisms have been shown to interfere with pesticide and polychlorinated biphenyls residue analysis. Using the accepted gas chromatographic methods for chlorinated hydrocarbon analyses, extracts from a variety of marine organisms show natural halogenated compounds with retention times easily confused with those of DDT, its metabolites, and the PCB's.

This study was designed to determine whether or not naturally occurring substances in the marine environment were capable of interfering with pesticide residue analysis. Dr. Howard Sleeper, a postdoctoral researcher supported under this project, organized and constructed a "standard" analytical sequence to determine the routinely discovered pollutants, DDT, DDD, DDE, the Arochlors 1254 and 1242, and the Dieldrin-Aldrin complex. This analytical method consists of a standardized hexane extraction sequence, followed by electron capture (^{63}Ni) gas chromatography (ECGC). This method has been widely accepted, since it provides selective detection of parts per billion of halogens in complex mixtures. Under these conditions, we could routinely detect the presence of ppb amounts of the above pollutants.

ECGC analysis of extracts

Since many marine organisms are now known to synthesize halogenated substances similar in structure to pollutant molecules, we extracted a series of selected organisms and subjected the extracts to ECGC analysis. Four red seaweeds (*Laurencia pacifica, L. subopposita, Chondria californica,* and *Plocamium cartilagineum*), an abundant local sponge (*Verongia* sp.), and one bacterium (*Chromobacterium* sp.) were selected, since each, with the exception of *Chondria,* is known to synthesize bromine- and chlorine-containing compounds. In each case, the major halogen-containing compounds have been isolated and structurally described. All six extracts showed compounds with the same detectability as pesticides which fall within the retention time limits associated with common polychlorinated biphenyls (Arochlor 1254 and Arochlor 1242) (See Fig. 1). *Laurencia* and *Chromobacterium* contain substances that could easily be confused with DDT or its metabolites.

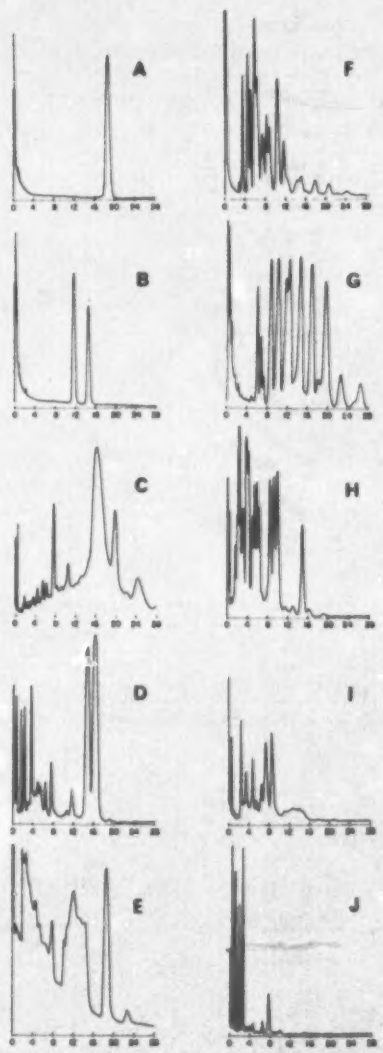


Fig. 1. Electron capture gas chromatographic traces of pesticide standards and hexane extracts from marine organisms: A) DDT, B) DDE (first peak) and DDD, C) *Laurencia pacifica,* D) *Laurencia subopposita,* E) *Chromobacterium* sp., F) Arochlor 1242, G) Arochlor 1254, H) *Plocamium cartilagineum,* I) *Verongia* sp., J) *Chondria californica*

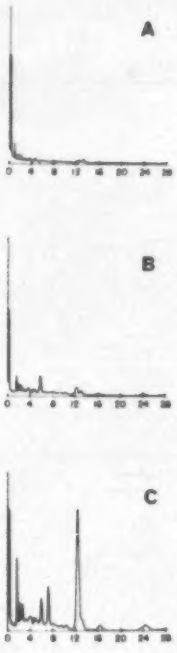


Fig. 2. Electron capture gas chromatographic traces of hexane extracts of tidepool water. The water samples were obtained from an isolated tidepool at low tide and extracted immediately. At the time of sampling, the air temperature was 27°C, the water temperature was 18.5°C and the day was partly cloudy. Neither Nanograde hexane nor 1 liter of Nanograde hexane condensed to 5ml contained any contaminating material. A) Time zero, 4μl; B) 1.5 hours, 4 μl; C) 3 hours, 4 μl

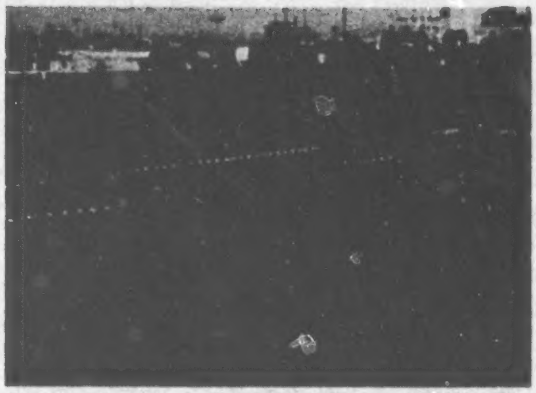
While these results show that standard pollutant analyses of the extracts of marine organisms are not possible, due to high levels of natural halogens, nothing can be stated concerning the natural substances which may be dissolved in seawater. Since the marine algae are potentially the largest source for naturally occurring halogenated compounds, we studied the chemical composition of an isolated tide pool containing large amounts of the red seaweeds *Plocamium* and *Corallina*, *inter alia*, as a function of time. Water samples were collected at regular intervals and analyzed by the ECGC method (see Fig. 2). As can be deduced from Fig. 2, the levels of natural halogens increase with time in this isolated water mass.

Implications for pollutant analysis

We conclude that the marine environment, particularly in continental shelf areas, poses a very difficult problem for halogen pollution analysis. Our data show conclusively that substances are produced through natural processes which are detected by ECGC methods and are indistinguishable from common pollutants. We suggest that newer methods, such as gas chromatography-mass spectrometry, be implemented, and that prior information obtained with ECGC techniques be carefully interpreted.

Publications

Fenical, W., and H. Sleeper, Marine natural projects: interference in pesticide residue analysis, *Nature*, in press.



Functional dynamic breakwater in operation in San Diego Bay

ENERGY RESOURCE RESEARCH AND DEVELOPMENT

Previously several energy-related studies were undertaken under the research program heading "Ocean Engineering". Energy research has now been specifically identified by the IMR Advisory Council as a program to provide a better focus for our activities. This program has as its objective the improvement of existing practices and the development of new technology to increase the contribution of marine resources to the exploration production, transportation and distribution aspects of energy at minimal social costs.

The exploratory research project at Scripps identified as "New Applied Developments" has been the source of ideas for major projects that have been undertaken in the past two years. One such idea concerns the possibility of tapping the potentially very large amounts of concentrated energy contained in the salinity gradient between freshwater and seawater.

An earlier research project on "Wave Climate Modification and Monitoring" has now proceeded to the point that a field-scale tethered float breakwater has been emplaced, and pilot tests have found it to be very suitable for wave protection of harbor facilities and marinas. There appears to be no obvious physical constraint precluding use under more severe open ocean wave conditions.

Wave Climate Modification in Harbors by Dynamic Breakwater

John D. Isaacs and Richard J. Seymour

Pilot tests with a small-scale tethered float breakwater have shown it to be very suitable for the protection of harbors, lakes and marinas, and have supported the dynamic analysis of such systems.

The first functional dynamic breakwater was installed for evaluation tests in San Diego Bay, and showed that it is very effective in attenuating both wind waves and ship wakes. It will be redeployed at the completion of these experiments to another permanent site where it will provide ship wake protection to fishing boats. The installation showed that a small-scale breakwater, suitable for harbors, lakes and marina protection, could be installed easily and economically. The performance of the breakwater also showed that the predictive model developed in previous work is equally effective in predicting performance at this scale.

Wave measuring instruments were installed to measure the wave height before entering and also behind the breakwater. These are connected by telephone lines to a computer at Scripps. This system is arranged so that it automatically samples the wave conditions; if the waves are big enough to be of interest, it makes records on magnetic tape for later analysis.

Laboratory work continued with scale models in the wave channel. Included in the project was a series of experiments in which the mooring load, or the force on the anchor line necessary to hold the free-floating breakwater in its proper position, was measured under a variety of wave conditions. At the same time a mathematical prediction of the mooring forces was developed in which the wave spectrum is an input for this very complex structure with hundreds of elements being loaded in varying amounts by the wave field. This work appears to be applicable to other complex compliant structures, such as drill platforms in deep water.

The special conditions involved in installations in very shallow water close to shore were simulated in a scale and computer model. Although the initial assumption was that performance would be very poor in shallow water because of the necessity for very short tethers, it now appears that excellent performance may be attainable using higher density floats, interacting with the increasing horizontal particle velocities as the waves transform in shallow water.

Performance predictions were made and parametric studies conducted to select the optimum design for ocean scale breakwaters. A design handbook for marina scale breakwaters is in draft.

Publications

Essoglou, M.E., R.J. Seymour and J.B. Berkeley, TFB: a transportable open ocean breakwater. *In* Proc. 11th Annual Conference of the Marine Technology Society, San Diego, September 1975.

Seymour, R.J., and J. D. Isaacs, Tethered float breakwaters. *In* Proc. Floating Breakwaters Conference, Marine Technical Rept. Ser. No. 24, Univ. Rhode Island, pp. 56-72 (1974). Also published as Univ. of Calif. Institute of Marine Resources, IMR Ref. 74-9.

Seymour, R.J., Wave induced loads on multi-element structures. *In* Proc. Symposium on Modeling Techniques for Waterways, Harbors and Coastal Engineering, San Francisco, September 1975.

Cooperating Organizations

State of California Department of Navigation and Ocean Development, Sacramento, California
U.S. Navy

Biological Effects of Waste-Heat Effluents of Coastal Power Plants

Berkeley
R/E-10

Ralph I. Smith and Cadet Hand

The effect on marine animals of long exposure to unnaturally warmed water, such as the outfall of large coastal power plants, is being studied with a view to evaluating the disturbance to the environment by such plants.

With the development of more and larger power plants, the problem of the effects of their so-called "waste heat" discharge becomes of increasing importance. On the one hand, protection of the environment dictates a relatively low temperature in the discharged cooling water; on the other hand, such standards impose problems of cost and engineering design. More and better biological information is needed in order that the control of "waste heat" be a reasonable compromise between engineering and environmental demands. The term "waste heat" is itself somewhat misleading, since this heat amounts to two thirds of the total energy output of a nuclear power plant, and biological studies may point the way to a more economical utilization of at least some of this "waste" in aquaculture and other economically advantageous projects.

Effect on mussels and barnacles

Our work had its inception in studies begun by Anson H. Hines on the growth and reproduction of mussels and barnacles in the warm-water effluent canal of the Morro Bay power plant of the Pacific Gas and Electric Company, which has provided much assistance. Originally conducted for two years with support from National Science Foundation grant GI-34932 to Professors G. J. Trezek and V. E. Schrock of the College of Engineering, University of California, Berkeley, Mr. Hines in 1974 received support from Sea Grant Project S/E-10 for the final year of his doctoral research.

The choice of mussels and barnacles reflects several considerations. First, both types of animals are sessile or attached, so must live fixed to one place and, if in a warm-water effluent channel, must in their growth and reproduction reflect the effects of long exposure to unnaturally warmed water. They are thus utilized in a long-term experiment such as could not readily be performed in a laboratory. Secondly, both types of animal are economically important: mussels as food organisms potentially valuable for mariculture, barnacles as ship- and harbor-fouling organisms often needing to be controlled. Information on their growth and reproduction could be of great practical as well as basic scientific value. Thirdly, both types are widespread, and there are closely related or comparable species in all parts of the world. Information obtained at Morro Bay thus has universal currency, and is available for comparative studies. Fourthly, each type is represented by two or more species in the outfall at Morro Bay, permitting an assessment of the variability found within one general animal type. It would be unwise to assume, on the basis of study of one barnacle species or one mussel species, that all barnacles and mussels behave alike, and in fact Anson Hines showed that they do not. Of the mussels, *Mytilus edulis* (the bay mussel) reproduced better in the warm outfall water than outside the warm region, but the California mussel, *M. californiensis*, reproduced less well. Of the barnacles, the reproduction of *Chthamalus fissus* in the outfall was not much affected, that of *Balanus glandula* was delayed and repressed, and that of *Tetraclita squamosa* caused to occur earlier than usual. More details of this study will be found in Mr. Hines' annual (terminal) report and will appear in full in his Ph.D. thesis and in subsequent articles in scientific journals.

Effect on sea anemone

Another common type of sessile marine animal is represented in the warm-water outfall at Morro Bay by three species of sea anemone: *Anthopleura elegantissima*, *A. xanthogrammica* ("great green anemone"), and *Diadumine franciscana*. These have been studied in 1974-75 by trainee Brian L. Jennison, whose work continues through the 1975-76 academic year. Of these, *D. franciscana* reproduces year-round in the outfall. The population of *A. xanthogrammica* is so sensitive to heat that very few individuals are able to inhabit the outfall. Intensive study of *A. elegantissima* in the outfall shows that, although the season of reproduction is not altered, the fat reserves necessary for reproduction are reduced. In the coming year Mr. Jennison will extend his

studies in order to clarify and separate the effects of high temperature and altered feeding rates on the outfall population of this sea anemone.

Useful base-line data

These studies add up to a body of knowledge that will be useful in the future as a base line against which to measure changes in the growth and reproduction of marine animals exposed to long-term warming of water by large coastal power plants. They should aid in the solution of engineering problems with predictable and/or minimal disturbance to the environment.

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Hines, A.H., Barnacle reproductive ecology, *Amer. Zool.*, 14, 1266 (1974). Abstract of paper presented at American Society of Zoologists' national meeting at Tucson, Arizona, December 1974.

Idem, Effects of a thermal outfall on reproduction in mussels and barnacles, *ibid.*, 15, 788 (1975). Abstract of paper presented at meeting of American Institute of Biological Sciences at Corvallis, Oregon, August 1975.

Jennison, B.L., The effect of increased temperature on reproduction in the sea anemone *Anthopleura elegantissima*, *ibid.*, 15, 787 (1975). Abstract of paper presented at American Society of Zoologists' national meeting at Corvallis, Oregon, August 1975.

Cooperating Organizations

Pacific Gas and Electric Company
Department of Engineering Research, San Ramon, California
Morro Bay power plant, California

New Applied Developments: Power from Salinity Gradients

San Diego
R/E-6

John D. Isaacs and Gerald L. Wick

Research is in progress to tap the potentially very large amounts of concentrated energy represented by the salinity gradient between fresh water and seawater. One of the most promising approaches to date seems that of using the osmotic pressure directly.

Because the power density of direct solar radiation is low, many schemes for utilizing this energy involve some form of energy reservoir. Proposals to use wind, waves, currents, ocean thermal gradients, and falling water have received their due attention. Another surprisingly large and concentrated reservoir of "solar" energy exists in the salinity differences between bodies of water. Every freshwater river flowing into the ocean represents an energy potential equivalent to a hydrostatic head of about 240 meters acting on the river flow. Salt brines, salt flats, and hypersaline sinks, which constitute a large part of this energy resource, have even higher energy densities.

The quantity, density, and flux of this stored energy have not been adequately assessed worldwide, but in this country the salinity gradient potential between freshwater rivers and the ocean is somewhat greater than the potential represented by the average elevation change of those rivers. Worldwide, the salinity gradient potential may be several times the amount of hydroelectric energy available.

It is not immediately obvious how this abundant energy can be used, since, when mixed, waters of different salinity undergo only very small changes in temperature and volume.

For the past several months, we have been investigating various possible schemes for mixing waters of different salinities to produce useful work. We have considered using the vapor pressure difference, osmotic pressure, and other physical properties of salt solutions. Reverse electrodialysis can be used to generate electric or ionic currents and produce electrical work or store electrochemical energy. A preliminary examination was made of reverse distillation using a Claude-type process to transport water vapor and condense it on salt water. It was found that such an approach is extremely inefficient, since, unlike other approaches, it is subject to the limitations of a heat engine. Furthermore, latent heat transport causes thermal disequilibrium, requiring large heat exchange. Other problems with this system are inherent in the Claude process, and include removal of dissolved gases, generation of partial vacuums over large quantities of water, prevention of precipitates, extraction of work from low pressure vapors, and as always, fouling and corrosion. Nonetheless, a small model was built inside a vacuum jar to demonstrate that a vapor flow would occur and could be made to do work. A small plastic sphere was suspended by the flowing gas for several days.

Recent experiments and calculations have concentrated on methods of using the osmotic pressure directly. If fresh and salt waters are placed on opposite sides of a membrane, fresh water will diffuse through the membrane, even opposing an hydrostatic pressure that can be tapped to produce useful work. A commercial water purification reverse osmosis membrane module is being adapted for this purpose. Future experiments are being designed to determine membrane operating characteristics, power production, and service life. Problems with clogging, polarization concentration, membrane compaction, and membrane flushing do not appear insurmountable.

This work was performed at the Foundation for Ocean Research.

Publications

Wick, G.L., and J.D. Isaacs, Salinity Power, IMR Ref. No. 75-9, Sept. 1975.

RAPID RESPONSE

Because commitment must be made to the regular planned research program almost a year in advance of beginning investigations, provision has been made for starting a limited number of projects within a short time frame. Projects which qualify for this kind of support fall within three general classes:

1. Research needed to address a problem of public importance and urgency.
2. Exploration of a potentially important new research idea to determine whether or not it should be included in future plans for the regular research program (basically a feasibility study).
3. A project included for funding in the regular research program which for various reasons should be initiated in advance of the starting date for regular projects.

Half Moon Bay Case Study

G. E. Goldman

This study estimates the local government cost and revenue impacts of six hypothetical residential and commercial growth scenarios for a 58 square mile coastal watershed basin surrounding Half Moon Bay. Generally, our analysis indicates that the more growth there is, the more per person public service costs tend to exceed government revenues.

The four "lower growth" alternatives utilized in this study test the Coastal Plan. The two less restrictive growth alternatives represent the general plans of San Mateo County and the City of Half Moon Bay. Calculation of per person costs and revenues were based on the existing 1974 population of 13,600, plus additional population growth depending upon the alternative being tested.

This cost-revenue analysis is the second of two studies sponsored by Sea Grant to determine the impact of different growth patterns on the Half Moon Bay subregion. The first phase involved the complex process of analyzing both the Coastal Plan's and the County and City General Plan's existing guidelines for future development. These guidelines were then applied to the study area on a parcel-by-parcel basis to determine potential patterns of residential and commercial development. This first phase was carried out by the University of California's Institute of Urban and Regional Development under the direction of Thomas Dickert and Jens Sorensen. The second phase of this project, the cost revenue portion, was conducted by the University of California's Cooperative Extension Service.

Three of the four "coastal plan" alternatives test the possibility of protecting open spaces by allowing only residential in-filling of partially developed areas. These "lower growth" alternatives also involve:

1) Additional constraints on transportation capacity which limit total population to 15,000 (1974 estimate is 13,600 people);
2) additional constraints on water and wastewater development and reallocation of population which limit total population to 19,000, and
3) without constraints on water and wastewater which limit total population to 24,000.

The fourth alternative uses the Coastal Plan as a guideline and follows existing zoning with concentrated development, leading to a total population of 27,000. The fifth and sixth scenarios tested allow greatest residential and commercial growth and follow the guidelines set in the general plans of the city of Half Moon Bay and San Mateo County. The total potential population growth for these alternatives is 54,000 and 61,000 respectively.

Second phase

The second phase involved the analysis of costs and revenues of nine governmental agencies for the 1973-74 fiscal year. These agencies include city, county, two school districts, two sanitary districts, a water district, and two fire districts. Interviews with many local and state government officials helped in determining the relationship of land use categories to governmental revenues and services. It was determined that costs beyond yearly operational expenditures would be necessary for new water, sewer, and fire facilities. Additional capital expenditures would be necessary for Alternatives 3 through 6 to maintain legally required service levels. Service requirements for alternatives 1 and 2 could be met using existing facilities. Additional school buildings might be paid for by the state through the school building aid law. This study also assumes that new, additional roads would be paid for by private developers and by state highway users' tax funds and would therefore not require local government revenues.

Our first graph shows the current revenues and expenditures on a per person basis and compares those with the six growth alternatives. The nine agencies are grouped together to give an overall view.

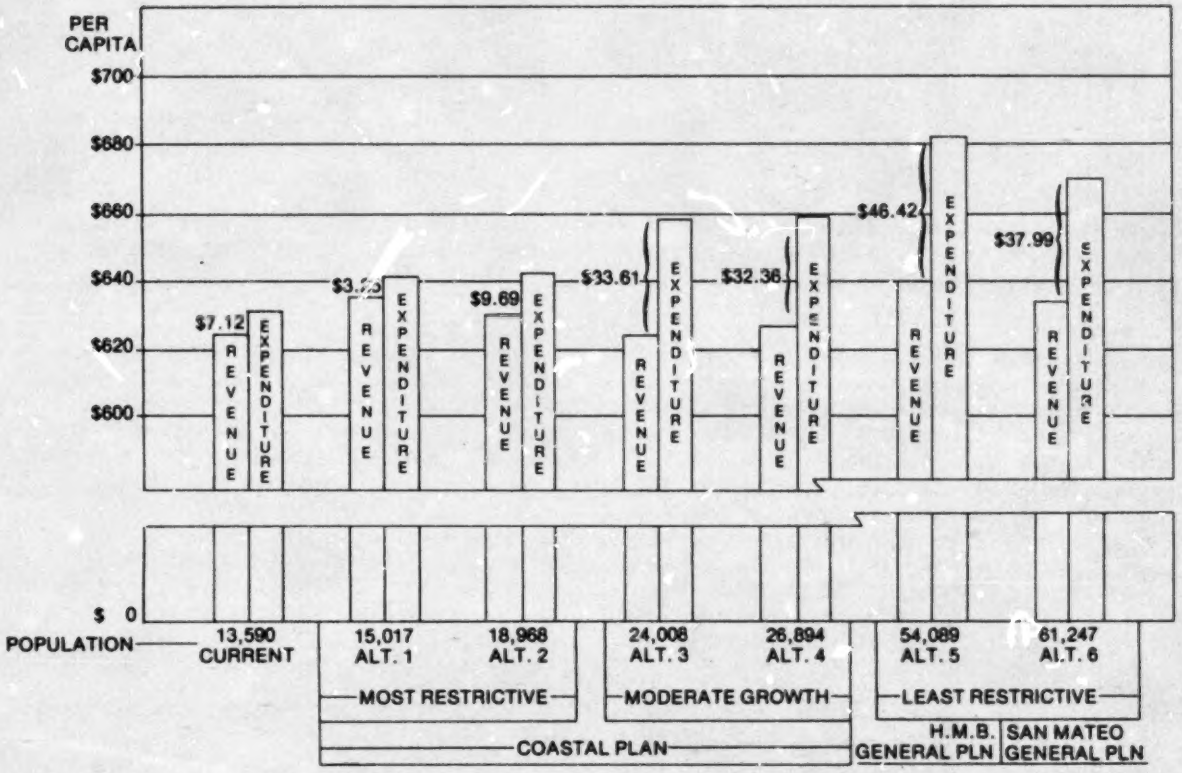
The second graph indicates the net difference between revenue and expenditures. The amount of excess revenues by agency is indicated above the line, while excess expenditures are below the line. The dollar amount indicated on the side of each bar (i.e., $7.12 for "current") is the net effect of all agencies' revenues less expenditures.

Conclusion

The expenditures exceed revenues by an ever increasing margin on a per person basis as the population gets larger. The ever widening gap is caused primarily by the additional water and wastewater capital costs.

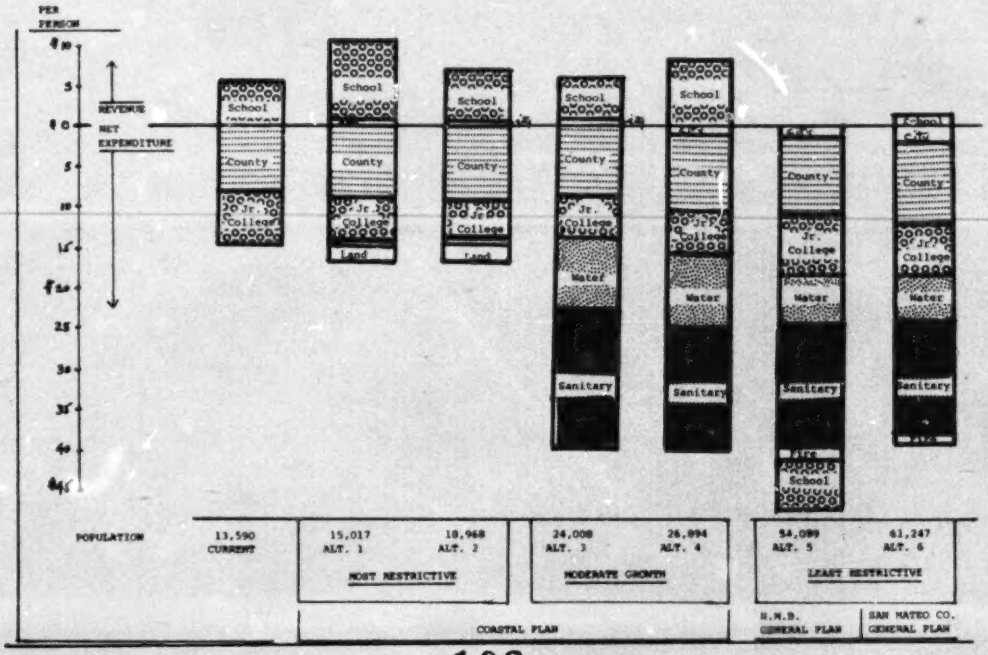
NINE AGENCY AGGREGATE: REVENUES AND EXPENDITURES

Current Plus Six Growth Scenarios



PER PERSON REVENUE LESS EXPENDITURE EQUALING NET: BY AGENCY

Current Plus Six Growth Scenarios



Report on Rapid Response Project on Policy Issues of the Seaward Side, With Special Respect to the California Coastal Plan

Berkeley
R/R-3B

Stanley Scott

In response to a request from the California Coastal Zone Conservation Commission for help in determining what its role should be in seaward jurisdiction, a four-month "Rapid Response" study was undertaken by the Institute of Governmental Studies.

From April through August 1975, approximately 55 knowledgeable individuals were interviewed for guidance on possible relevant policies to be included in the coastal plan that was recently delivered to the California Legislature. In addition, the "Rapid Response" project was designed to initiate a longer study of the intergovernmental issues of the seaward side. The interviews addressed a number of substantive problems of sea and coastal conservation and development, including: seabed mining; undersea oil and gas exploration and development (including the onshore effects of such activities); fisheries beyond the territorial sea; offshore dumping of sewage, toxic substances and other hazardous or potentially damaging materials; military testing and related activities; ports and offhsore terminals; shipping and related concerns; sports and recreational activities; and scientific research in distant waters.

From this we concluded that the California coastal plan draft as it stood in August, 1975, contained adequate material on seaward-side issues. But we also found a great need for the coastal commissions, and other appropriate California authorities, to develop future expertise and "intelligence" on seaward-side issues, in order to be prepared to make policy recommendations to the Legislature, Governor, Congress, and the Law of the Sea discussions. A memorandum was submitted to Joseph Bodovitz, Executive Director, California Coastal Zone Conservation Commission, outlining these ideas and enclosing other policy statements and back-up material.

Cooperating Organizations
California Coastal Zone Conservation Commission, San Francisco, California

Assessment of Impacts of Parkland Acquisition and Development

Berkeley
R/R-3C

C. F. McGuire, Abe Cofnas, Peter May, and Paul Newacheck

The California Coastal Zone Conservation Commission in February 1975 requested a study be made of the effects of park acquisition on local governments. One reason for their interest in such information was the proposed extensive acquisition of land for preservation and recreational use along the California coast. The Commission staff members believed that the planned acquisition policies would meet with opposition from local governments. Thus, as a response to possible objections to park acquisition, a framework was needed for pinpointing possible benefits and costs. Our research task was to develop and outline methods for assessing the impacts of acquisition and development, and we believe our study lays the basis for such an assessment by different levels of government.

Park acquisition and development have had three types of rationale—economic, social, and environmental. The economic rationale has been advanced in asserting that parks provide some kind of dollar impact to an area. The reasoning is that parks create a stimulus to tourism leading to more spending and other benefits in the form of new jobs, increased income for local areas, and more tax revenue for government. The social justification of park development invokes the value of recreational activities to citizens. With the trend towards a greater amount of leisure time in this country, one increasingly hears the argument that more parks are needed for outdoor recreation. Finally, the environmental rationale for more parkland entails the argument of preserving scarce natural resources.

Loss in tax revenue

Despite the positive effects of parks underscored by the three areas of impact, there has been opposition to increased conversion of private land into public parks. Most County tax assessors' offices would point to the loss in tax revenue to counties from removal of land. This opposition on fiscal grounds is within the general context of limited revenues to local governments. Thus, when state governments support further acquisitions of parks, local jurisdictions perceive state policies as being against their interests. In a sense, local governments act to maximize their revenues, while state agencies recommending park acquisitions have different aims.

The disparity in aims between local and state levels makes it difficult to assess the impacts of park acquisition and development in a way where all parties involved can use a common impact measure. In other words, it makes little sense to local officials for park studies to measure the tourist dollars created by parks when the relevant boundary for assessing impacts is the tax districts affected by acquisitions. Indeed, there might be a basic disagreement as to relevant boundary for analyzing impacts. The state and those groups advocating parks on environmental and social grounds have as their clients not the people of the local community affected, but the entire state or region. This problem of a common framework for analysis is an enduring one.

However, the value of knowing the pattern of impacts of park acquisition and development on local communities remains great. Determining those impacts which are beneficial and those which are detrimental to local interests can improve the allocation of open space in the state. Information on the costs to local governments of park acquisition make possible policies that seek to reduce the costs or provide offsetting benefits. In other words, measuring the economic and fiscal impacts of park acquisition on local regions allows state and local governments to accommodate both positive and negative impacts. With the local boundary as the relevant base for assessing impacts, the ability of both state and locals to improve their situation increases.

If our assertion that the proper basis for park impact assessment includes local regions is obvious, it nevertheless has been largely ignored throughout the country. Numerous studies of park impacts have been made, but few address the effects at the local level. Still, those that we have seen that have been locally oriented do not employ a comprehensive method for evaluating impacts. A selected review of the park impact literature demonstrates this lacking impact framework.

For the purpose of setting out a comprehensive framework of park impacts, we have classified effects into several broad

categories of activities. Based upon this classification, an assessment of park impacts to local governments can be developed.

A CLASSIFICATION OF PARK IMPACTS

Park-related activities and land use:
The impacts that can be readily attributed to park development and acquisition at the site itself. They include changes in the use of the land, effects on demand, visitor expenditure, and employment.

Changes in surrounding activities:
The impacts not as visible and often not discussed in the literature. These are effects on land use activity surrounding parks, changes in demand at other recreational sites, and changes in property values.

Local revenues and costs:
The fiscal consequences of changes resulting from park acquisition and development.

Regional economic effect:
Included here are the indirect effects of introducing a change in the local economy. The impact of park acquisition and development affect primarily the flow of spending in the local area and region. In turn, there are multiplier effects on local income and jobs.

In our study we applied our framework to current proposed park acquisition plans at a specific site—Lake Earl in Del Norte County. Our site application did not involve a complete impact assessment, but it showed the direction of economic impacts in that area.

Use of analysis

We hope that the information provided will be useful in a decision-making context at both the county and state levels. In particular, advocates of acquiring more park land can utilize this analysis to lay down policies that reduce local costs where they cannot be avoided. This can be done only by understanding the underlying economic causes of negative effects and the most effective sources of compensations. For County officials and others opposed to further park development, our results could be of use in initiating a process of negotiation and debate based on sound economic grounds.

Surfperch Mariculture: A Pilot Study

Santa Cruz
R/R-9

Kenneth S. Norris

A pilot study in mariculture has been conducted with the live-bearing striped perch, which was found most suitable for this purpose. The fish were cultured in a 1000-gallon recycling artificial seawater system, with specially designed refrigeration system and tank hoods for precise control of temperature and light.

The main objective of this project was to investigate the suitability of selected species of live-bearing surfperch (family *Embiotocidae*) for mariculture. Attributes of the surfperches which make them highly attractive for mariculture are their live-bearing reproductive strategy, and the very generalized diets of some species. The problem of maintaining sensitive eggs and larvae is eliminated, and the wide range of food items taken by surfperches in nature indicates they may be easily adapted in the laboratory to an inexpensive artificial food source.

Species selected

As a result of an investigation of food habits in a number of embiotocid species, it was concluded that the species feeding on the widest ranges of food items are the black perch, *Embiotoca jacksoni*, and the striped perch, *E. lateralis*. Algae appear in the guts of both species, but the question of its nutritional value remains to be investigated.

These two species are among the largest in the embiotocid family, and in fact rank next in size to three species characterized by highly selective carnivorous diets. Their maximum length of over 15 inches makes them quite acceptable as "pan fish." They are taken in small numbers by sport and commercial fishermen, and perhaps in larger numbers by spear fishermen, who have greater access to their habitats in kelp and eelgrass beds.

It was decided to concentrate on *Embiotoca lateralis* in preference to *E. jacksoni* because of its much higher local availability; also, our work indicates a slightly higher fecundity and growth rate in *E. lateralis*. However, we are continuing to keep *E. jacksoni* in small numbers, and these may be increased in spring and summer when *E. jacksoni* is available more plentifully.

Seawater system built

The seawater system for this project was designed with particular needs in mind. It allows us to keep animals under controlled temperature and light regimes, to manipulate stock densities, to isolate animals for experiments or treatment of disease, and to recognize individual animals in the tanks without disturbing them. This recycling, closed artificial seawater system consists of two rectangular fiberglass tanks (42 in x 72 in x 43 in), each with a capacity of approximately 500 gallons, a large (2 ft x 4 ft x 2 ft) sand-and-gravel filter for each, a specially designed refrigeration system, and double-layered plywood tank hoods fitted with fluorescent bulbs controlled by timers and dimmers. For isolating animals, a series of five 30-gallon aquaria with dolomite and activated charcoal filters are kept either at ambient temperature or in a cold room.

Maintenance of animals in the laboratory

Embiotocids have proved to be hardy animals in the laboratory, adapting to rather wide ranges of temperature and salinity. We have maintained several species for short periods of time, and have dealt with important problems of disease, escapement, and feeding. Animals learn to feed on commercial trout food after being fed fresh or frozen fish and shellfish for a short period of time.

Work on optimum rations, feeding times, and temperatures for growth is continuing. As a result of these investigations, we plan to estimate the economic feasibility and efficiency of mariculture of the live-bearing surfperch.

Cooperating Organizations

California Department of Fish and Game, Monterey, California

Moss Landing Marine Laboratories, California

Steinhart Aquarium, Calif. Academy of Sciences, San Francisco

University of California at Santa Barbara, Marine Science Institute

Histamine Toxicity from Fish Products

Davis
R/H-2

W. D. Brown

A literature survey has been initiated on histamine toxicity from fish products. Also, research is under way to evaluate and improve existing methods of analysis of histamine.

Efforts during the early part of this project were directed to accumulation of an extensive collection of references. There is a great deal of literature on pharmacological effects of histamine and a fair amount of older literature dealing with scombroid toxicity. However no review or literature survey could be found that was directly applicable to the problem. The original survey has been updated periodically and now includes well over 100 references that bear directly on the problem.

Another major effort was to evaluate existing analytical procedures for the analysis of histamine. The so-called "official" method, i.e. that which appears in the Association of Official Agricultural Chemists (AOAC) handbook, is tedious and not suited for routine use. Having a relatively simple and routine method is of crucial importance in order that sizable numbers of samples may be assayed. This will also help to insure maximum interaction among different interested groups in that each can use the same method. Five methods have been evaluated, including one presently under consideration for use by the Federal Food and Drug Administration. One method has been selected on the basis of convenience and accuracy, and it gives results comparable to those obtained by the AOAC method. Another method was shown not to be applicable to canned fish samples.

An informal "histamine group" has been established and includes a number of individuals from various departments on the Davis and Berkeley campuses of the University of California and representatives of the National Canners Association in Berkeley. Bibliographies and summaries of early findings have been supplied to industrial personnel via the Tuna Research Foundation and the California Seafood Institute Research Committee.

Cooperating Organizations
California Seafood Institute, Sacramento, California
National Canners Association, Berkeley, California
Tuna Research Foundation, Terminal Island, California

PROGRAM SUMMARY

PROGRAM DEVELOPMENT	FY72	FY73	FY74	FY75
PROGRAM MANAGEMENT				
Management and Program Development (Frautschy)	O	O	O	O
New Projects (Frautschy)	N	O	O	O
EDUCATION/TRAINING				
Graduate Education in Applied Ocean Science (Anderson)	O		-	-
Sea Grant Trainees (Frautschy)	O		O	O
Scientific Diving Supervisor Training (Stewart)	C	-	-	-
Undergraduate Training in Marine Technology (Flittner)	O	O	R	C
Sea Grant Educational Services (Hurley)	-	-	N/C	-
ADVISORY				
Ocean Education for the Public (Wilkie)	O	O	O	O
Marine Advisory Services (Cummings)	N	O	O	O
Publications and Public Advisory Services (Sullivan)	-	N	O	O
Ocean Engineering Data Center (Johnson)	-	N	C	-
Geophysical and Geological Data Center for Information on Petroleum Resources (Chase)	C	-	-	-
Improvement of Methods of Predicting Sea-Surface Temperatures (Gibson)	C	-	-	-
Marine Advisory Services Expansion (Flittner)	C	-	-	-
San Diego [illegible] Review (Bratton)	-		N/C	-
COASTAL ZONE STUDIES				
Predictive Methods and Information Systems in Coastal Zone Management (Twiss)	N	O	R	C
Physical Criteria For Coastal Planning (Inman)	O	O	O	O
Biological and Ecological Studies of Normal Populations (Newman)	C	-	-	-
Ecological Studies of the Nearshore Zone (Dayton)	O	O	O	O
Ecology of Santa Cruz and San Mateo County Coast (Doyle)	N	O	C	-
Natural Seepage in the Santa Barbara Channel: Physiochemical Aspects (Mikola)	N	C	-	-
An Investigation of the Seismicity and Earthquake Hazards of the Santa Barbara Channel Area (Sylvester)	N	C	-	-
Sea Coast Planning Project (Hetrick, *et al.*)	N	C	-	-
Monitoring of Pollution Parameters in San Francisco Bay (Wilde)	-	N	C	-
Recreation Resources of Los Angeles County Coast (Egstrom)	-	N	C	-
Trace Metal Analysis of Oily Beach Pollutants in the Santa Barbara Channel (Mikola)	N	C	-	-
Organizational Arrangements for Coastal Management (Lee, Scott)	-	-	N/C	-
Development and Assessment of Legally Permissible Methods for Coastal Management (Heyman)	-	-	N	T*
Experimental Study of the Tomales Bay "Sneaker Wave" (Fischer)	-	-	N/C	-
Legal Techniques for Marine Resources Management (Snydan)	-	-	N/C	-
Design of a Computer-Automated Map (Pepper)	-	-	N/C	-
Determination of Physical Changes of Southern California Coastal Lagoons (Phillips)	-	-	-	N/C
Oceanographic Inventory of the Southern California Shelf (Fischer, Berry)	-	-	-	N
Subtidal Ecology of Carmel Bay (Thompson)	-	-	-	N
Management of Beach and Dune Vegetation (Barbour)	-	-	-	N
Diving Safety Research Project (Egstrom)	-	-	-	N
FISHERIES/AQUACULTURE				
Uses of Waste in Aquaculture (Cooper, Holmes)	-	N	C	-
Rearing of Larval Fishes (Lasker)	O	C	-	-
Economics of Aquaculture (Johnston)	-	N	O	O
Aquaculture of the American Lobster (Shleser)	N	O	O	O
Studies of Vertical Migration of Zooplankton (Enright, Isaacs)	C	-	-	-
Use of Thermal Effluent in Aquaculture (Ford, Van Olst)	O	C	R	O
California Spiny Lobster Growth (Dexter)	O	T*	-	-

PROGRAM DEVELOPMENT	FY72	FY73	FY74	FY75
FISHERIES/AQUACULTURE (cont'd)				
Historical Levels, Areas, and Routes of Pesticides in the Plankton and Fish of the California Current (Longhurst, Lasker)	C	-	-	-
Protective Measures for Lobster Aquaculture (Schapiro, Steenbergen)	O	R	O	O
California Spiny Lobster Fishery and Related Population Characteristics During Period of Reduced Fishing Effort (Farris)	C	-		-
Abalone Culture (Leighton, Wilson)	N	C	-	-
Seaweed Resource Management (Neushul, Coon)	N	O	O	C
Gelidium Resource Management (Barilotti)	-	N	C	-
Salt-Tolerant Plants (Epstein)	-	N	O	O
Fishes of the Santa Barbara Kelp Forest (Ebeling)	O	C	-	-
The Juvenilizing Factor in Crustacean Eyestalks (Faulkner, O'Connor)	C	-	-	-
Ecology of Benthic Herbivores in the Sea (Connell, Murdoch)	C	-	-	-
Ecosystem Studies and Mariculture Potential of a Coastal Lagoon (Holmes)	C	-	-	-
Toxins from Marine Dinoflagellates (Rapoport)	-	-	N	C*
Mass Culture of Toxic Dinoflagellates (Haxo)	-	-	N	C
Economics of Marine Resources Decision Modeling (Sullivan)	N	O	R	C
Feasibility of a Black Cod Trap Fishery in Monterey Bay (Caillet)	-	-	C	-
Development of a Commercial Aquaculture System for the Crab *Scylla Serrata* (Harrison)	-	-	-	N
Marine Ecology of the Central California Coast (Doyle)	-	-	N	C
Kelp Forest Ecology of the Central California Coast (Pearse)	-	-	N	C
The California Market Squid Fishery (Thompson, Frey)	-	-	-	N
Optimal Management of Sea Urchin Fisheries (Dayton)	-	-	-	N
Effect of Fishing Sea Urchins on the Marine Ecosystem (Connell)	-	-	-	N
Determination of Appropriate Levels of Fees for Vessels Fishing for Yellowfin Tuna in the Eastern Tropical Pacific (Flagg)	-	-	-	N/C
MARINE PRODUCTS				
New Antioxidants for Marine Lipids (Olcott)	N	O	R	O
Studies of Fish Muscle Proteins (Brown)	N	O	O	O
Natural Fermentation of Marine Products (Crisan, Miller)	N	O	O	C
Pharmaceuticals from Marine Organisms (Faulkner)	O	O	R	O
Natural Compounds from Marine Organisms (Sims)	N	O	C	-
Seaweed Products: Application in Algae Control, Mariculture and Agriculture (Fenical)	-	-	-	N
Naturally Occurring Halogenated Compounds: Their Interference in Pesticide Pollution Analysis (Fenical)	-	-	-	N/C
OCEAN ENGINEERING				
Enhancement of Natural Marine Productivity by Artificial Upwelling (Isaacs, Schmitt)	C	-	-	-
Wave Climate Modification in Harbors by Dynamic Breakwater (Isaacs)	-	N	O	R
Unmanned Sea Floor Work Systems (Anderson)	O	C	-	-
Engineering Properties of Sea Floor Sediments (Noorany)	N	O	C	-
Synthesis of Forces on Marine Structures (Paulling)	N/C	-	-	-
Underwater Cable Dynamics (Webster)	N	C	-	-
New Applied Developments (Isaacs)	O	O	O	C
Acoustic Holographic System for Underwater Search (Wade)	N/C	-	-	-
Composite Materials for Ocean Construction (Tatelman)	N	C	-	-
Biological Effects of Waste Heat Effluents of Coastal Power Plants (Smith, Hanf)	-	-	-	N

N = New Project
O = Ongoing Project
R = Restructured Project
C = Completed Project
T = Terminated Project
*No Final Report

ACTIVITY BUDGET SHEET
1974-75

	NOAA Grant Funds	Matching Funds
MARINE RESOURCES DEVELOPMENT		
Aquaculture	307,691	362,770
Living Resources (other)	131,600	156,559
Mineral Resources	36,279	42,800
Marine Biomedicinals & Extracts	42,340	36,911
SOCIO-ECONOMIC & LEGAL STUDIES		
Marine Economics	21,714	15,316
Ocean Law	5,593	10,943
MARINE TECHNOLOGY RESEARCH & DEVELOPMENT		
Ocean Engineering	70,611	123,349
Resource Recovery & Utilization	92,529	111,670
MARINE ENVIRONMENTAL RESEARCH		
Research & Studies in Direct Support of Coastal Management Decisions	60,571	23,959
Ecosystems Research	52,338	44,048
Pollution Studies	6,240	9,933
Applied Oceanography	96,596	50,742
MARINE EDUCATION & TRAINING		
Vocational Marine Technician Training	6,077	1,000
Other Education (Sea Grant Trainees & Interns)	225,760	65,840
ADVISORY SERVICES		
Extension Programs	179,524	121,513
Other Advisory Services	63,801	62,844
PROGRAM MANAGEMENT & DEVELOPMENT		
Program Administration	198,111	95,866
Program Development	53,825	5,602
TOTAL	$1,661,200	$1,341,685

MATCHING FUND SOURCE
1974-75

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Aquarium Museum Docents
California Cooperative Oceanic Fisheries Investigation
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Editor's note: Supplementary material and Trainee reports for individual projects are available at the Sea Grant Publications Office. See address below.

Designed and edited by Robert Powell
Drawings by Christina Good

University of California Sea Grant College Program
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